Exhibit 1
(1 of 8)

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Lives Saved by Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012

Passenger Cars and LTVs

With Reviews of 26 FMVSS and the Effectiveness
Of Their Associated Safety Technologies in
Reducing Fatalities, Injuries, and Crashes

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16. Abstract

NHTSA began in 1975 to evaluate the effectiveness of vehicle safety technologies associated with the Federal Motor Vehicle Safety Standards. By June 2014, NHTSA had evaluated the effectiveness of virtually all the life-saving technologies introduced in passenger cars, pickup trucks, SUVs, and vans from about 1960 up through about 2010. A statistical model estimates the number of lives saved from 1960 to 2012 by the combination of these life-saving technologies. Fatality Analysis Reporting System (FARS) data for 1975 to 2012 documents the actual crash fatalities in vehicles that, especially in recent years, include many safety technologies. Using NHTSA's published effectiveness estimates, the model estimates how many people would have died if the vehicles had not been equipped with any of the safety technologies. In addition to equipment compliant with specific FMVSS in effect at that time, the model tallies lives saved by installations in advance of the FMVSS, back to 1960, and by non-compulsory improvements, such as pretensioners and load limiters for seat belts. FARS data has been available since 1975, but an extension of the model allows estimates of lives saved in 1960 to 1974.

A previous NHTSA study using the same methods estimated that vehicle safety technologies had saved 328,551 lives from 1960 through 2002. The agency now estimates 613,501 lives saved from 1960 through 2012. The annual number of lives saved grew from 115 in 1960, when a small number of people used lap belts, to 27,621 in 2012, when most cars and LTVs were equipped with numerous modern safety technologies and belt use on the road achieved 86 percent.

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ABS	antilock brake system
ACIR	Automotive Crash Injury Research, a crash data file of the 1950s and 1960s
ACTS	Automotive Coalition for Traffic Safety (before 1999, American Coalition for Traffic Safety)
AIS	abbreviated injury scale; the levels of this scale are: 0 = uninjured, 1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, and 6 = maximum
AMC	American Motors Corporation
ANPRM	advance notice of proposed rulemaking
ANSI	American National Standards Institute
ATD	anthropomorphic test device (dummy)
BMW	Bayerische Motoren Werke
CATMOD	categorical models procedure in SAS
CDS	Crashworthiness Data System of NASS
CFR	Code of Federal Regulations; up-to-date text of NHTSA regulations may be downloaded from the electronic CFR, Title 49, www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/Title49/49tab_02.tpl. Regulations other than FMVSS are referenced as Part numbers (e.g., Part 563, "Event data recorders"). FMVSS are referenced as Part 571 followed by the FMVSS number (e.g., Part 571.103 = FMVSS No. 103, "Windshield defrosting and defogging systems")
CHMSL	center high-mounted stop lamp
CMVSS	Canadian motor vehicle safety standard
CPU	central processing unit
CRASH	Calspan reconstruction of accident speeds on the highway
CUV	crossover utility vehicle
CY	calendar year
DMV	department of motor vehicles

DOF	direction of force (a variable in CDS and other crash databases)
DRL	daytime running lights
ECE	Economic Commission for Europe
EMS	emergency medical services
ESC	electronic stability control
FARS	Fatality Analysis Reporting System (a census of fatal crashes in the United States since 1975)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
FMH	free-motion headform for testing upper interior components
FMVSS	Federal Motor Vehicle Safety Standard
GAD	general area of damage (a variable in CDS and other crash databases)
GES	General Estimates System of NASS
GM	General Motors
GSA	General Services Administration of the Federal government
GTR	global technical regulation
GVWR	gross vehicle weight rating (specified by the manufacturer, equals the vehicle's curb weight plus maximum recommended loading)
HIC	head injury criterion
HPR	high penetration resistant windshield
HSL	Highway Safety Literature, an on-line literature database that is a subfile of the automated Transportation Research Information Service (TRIS) file, accessible at trid.trb.org.
ICC	Interstate Commerce Commission
ICD-10	International Classification of Diseases, 10th revision
IIHS	Insurance Institute for Highway Safety

LATCH	lower anchors and tethers for children
LED	light-emitting diode
LTV	light trucks and vans (includes pickup trucks, SUVs, minivans and full-sized vans)
MCOD	multiple cause of death file, a supplement to FARS since 1987, listing causes of death from the occupant's death certificate
MDAI	multidisciplinary accident investigations (a file of in-depth crash investigations conducted by NHTSA and others, 1967-78)
MDB	moving deformable barrier
MVMA2D	Motor Vehicle Manufacturers' Association's 2-dimensional computer simulation of the occupant's motion in a frontal crash
MY	model year
NASS	National Automotive Sampling System (a probability sample of police-reported crashes in the United States since 1979, investigated in detail)
NCAP	New Car Assessment Program (consumer information supplied by NHTSA on the safety of new cars and LTVs, based on test results, since 1979)
NCSA	National Center for Statistics and Analysis, NHTSA
NCSS	National Crash Severity Study (a probability sample of police-reported towaway crashes in seven multicounty areas, 1977-79, investigated in detail)
NHTSA	National Highway Traffic Safety Administration
NMVCCS	National Motor Vehicle Crash Causation Study
NOPUS	National Occupant Protection Use Survey (statistics for the United States, since 1994, from a national observational survey based on a probability sample)
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
RF	right front
RSEP	Restraint Systems Evaluation Project (a probability sample of police-reported towaway crashes involvements of model year 1973-75 cars in five urban or multicounty areas, 1974-75, investigated in detail)

RWAL	rear-wheel antilock brake system
SAE	Society of Automotive Engineers
SAS	statistical and database management software produced by SAS Institute, Inc.
SCI	Special Crash Investigations, NHTSA’s National Center for Statistics and Analysis
SID	side impact dummy
SSF	static stability factor (half of the vehicle’s track width divided by the height of its center of gravity)
SUV	sport utility vehicle
TPMS	tire pressure monitoring system
TREAD Act	Transportation Recall Enhancement, Accountability, and Documentation Act
TTI	thoracic trauma index
TTI(d)	thoracic trauma index for the dummy in a side-impact test
TTMA	Truck Trailer Manufacturers Association
UMTRI	University of Michigan Transportation Research Institute
VIN	Vehicle Identification Number
VMT	vehicle miles of travel
VW	Volkswagen

A REVOLUTION IN SAFETY AND HEALTH

For occupants of cars and LTVs (pickup trucks, SUVs, and vans), the fatality rate per vehicle mile of travel dropped by an astounding 81 percent from 1960 to 2012. In CY 1960, 28,183 drivers and passengers died in 662 billion VMT. By 2012, only 21,696 occupants died in 2,653 billion VMT. The green line and squares in Figure A track the VMT fatality rate for car/LTV occupants, indexed to 100 in 1960, as it descends to 19 by 2012.

At least four developments in technology and social science can take credit for some of the reduction:

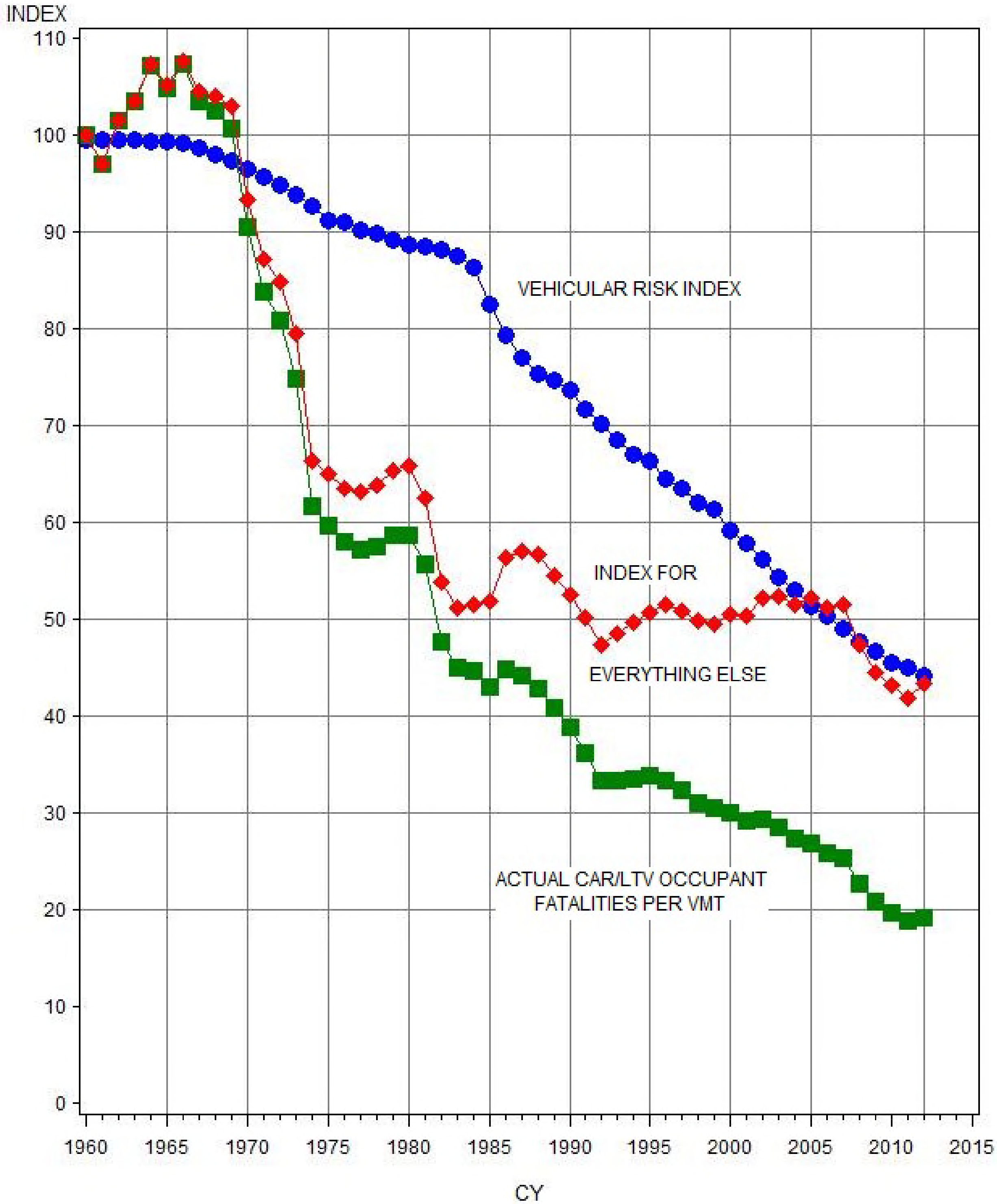
- Vehicle safety technologies such as seat belts, air bags, and electronic stability control (ESC), combined with programs to increase the use of belts and other safety equipment;
- Safer roads, including major new infrastructure such as the Interstate Highway System and gradual improvements to existing roads, such as guardrails;
- Behavioral programs to make people drive more safely; above all, laws and programs to abate drunk driving; and
- Better medicine: quicker arrival of EMS, more effective treatment in transport and at the trauma center, and any developments in surgery and medicine that made injuries more survivable than they used to be.

In addition, the past 53 years have witnessed important demographic and geographic trends that would likely have lowered the VMT fatality rate substantially even without advances in science: a shrinking population of young drivers (who have high fatality rates), a much larger share of VMT for female drivers (who have low fatality rates, specifically, a low incidence of drunk driving), and population movement from rural to metropolitan areas (where fatality risk per mile is lower). At times however, demographic and geographic trends have worked in the opposite direction, such as a growing proportion of older drivers (who have high fatality rates) and movement within metropolitan areas from central cities to more sparsely populated outer suburbs.[1]

This report focuses exclusively on the fatality reduction attributable to vehicle safety technologies introduced since 1956 (when factory-installed lap belts first became optionally available on some cars) and, from 1968 onwards, largely associated with the Federal Motor Vehicle Safety Standards and/or related programs such as safety ratings. It develops a **vehicular fatality-risk index** by calendar year, tracked by the blue circles in Figure A, that measures how much safer the average car or LTV on the road has become relative to a car or LTV on the road in 1955.

[1] The chapter titled "Car/LTV occupant fatalities per 100,000,000 VMT" in Part 2 of this report presents additional discussion, including references, of factors (other than vehicle safety technologies) that influenced fatality rates between 1960 and 2012.

FIGURE A: FATALITY-RISK INDICES BY CALENDAR YEAR (1960 = 100)
FOR CAR AND LTV OCCUPANTS



The index stayed essentially unchanged from 1955 (100) to 1960 (99.6), but it had dropped to 44 by 2012. In other words, this report estimates that the fatality risk in the average car or LTV on the road in 2012 would be 56 percent lower than in the average vehicle on the road in 1960, even given the same exposure, drivers, roadways, and medicine. The reduction includes the effects of crash avoidance technologies such as ESC, occupant protection technologies such as seat belts and air bags, and programs to increase belt use. The report estimates that vehicle safety technologies saved 613,501 lives from 1960 through 2012, including 27,621 in 2012.

The estimate of lives saved by vehicle safety technologies is not based on some kind of multivariate or time-series analysis of the VMT fatality rates over the years, but on a review of the occupant fatality cases in NHTSA's Fatality Analysis Reporting System. Since 1975, the agency has issued 82 retrospective evaluations of individual FMVSS or related vehicle technologies, based on statistical analyses of the agency's crash data files. The evaluations estimated the fatality-reducing effectiveness, if any, of each technology, relative to vehicles produced just before its introduction (i.e., incorporating every earlier technology, except the one being evaluated).

Thus, if a vehicle is equipped with multiple safety technologies, their combined fatality-reducing effectiveness is the composite of the individual effectiveness estimates. The individual (and the combined) effectiveness, of course, may depend on the type of crash (e.g., frontal air bags are most effective in directly frontal impacts), the occupant's seating position and age, and whether the occupant made correct use of the technology (e.g., buckled up). But the average composite effect of the safety technologies in cars and LTVs on the road in CY 2012 is a 56-percent reduction of fatality risk relative to what it would have been if the same vehicles had not been equipped with any of those technologies – if the vehicles had incorporated only the 1955 level of safety. This report considers every FARS fatality case in 2012 (and also in earlier years), identifies what safety technologies were in the vehicle, and estimates the hypothetical additional risk if none of those technologies had been present in the vehicle.

Figure A shows that the 56-percent reduction in the vehicular risk index from 1960 to 2012, although remarkable, does not fully explain the overall 81-percent reduction in the VMT fatality rate during those years. The red diamonds in Figure A index the effects of "everything else" – everything except the benefits of vehicle safety technologies. The "everything else" index is 43 in 2012, almost the same as the vehicular risk index (44). In other words, the net effect from 1960 to 2012 of "everything else," a 57-percent reduction, is almost identical to the 56-percent reduction attributable to vehicle safety improvement.[2] But Figure A shows the trend in the vehicular risk index differs from the trend in "everything else" in several important ways:

- The vehicular risk index tells a story of uninterrupted improvement; each year is lower than the one before it. The red diamonds zigzag up and down in response to demographic trends and transient phenomena such as an energy crisis, fuel-price increases, or economic slowdowns.

[2] The index of "everything else" is computed by dividing the VMT-rate index by the vehicular index and then multiplying by 100. For example, in 2012, the VMT-rate index is 19, the vehicular index is 44, and the index of everything else is 100 x (19/44) = 43.

- The vehicular risk index changes gradually. Even a highly effective technology such as ESC needs some years to demonstrate its efficacy, some years of lead-time before it can be built into all new vehicles, and quite a few years before vehicles with ESC replace all the older vehicles on the road that do not have it. The only abrupt change (for the better) is from 1984 to 1988, when belt-use laws in the States suddenly prompted millions of people to start buckling up the belts that had already been in their vehicles for years.

- The great reduction in the index of "everything else" is from 1965, when the large cohort of baby-boomers born just after World War II began to drive until 1975, when this cohort entered their late 20s, an age when fatal-crash involvement rates are substantially lower than in adolescence. The 1965-to-1975 decade also saw major new infrastructure such as completion of many Interstate highways, extensive urbanization, and increased numbers of women working outside the home (an influx of low-risk VMT); also, toward the end of the decade, an energy crisis and the national 55 mph speed limit. In 1975, the vehicular risk index was still above 90; even though the initial FMVSS arrived in the 1960s, there were still many pre-FMVSS vehicles on the road until the mid-1970s.

- The large, steady reduction in the vehicular risk index begins after 1984 and does not stop. By contrast, the trend in the red diamonds fluctuates in response to a range of factors affecting traffic volumes and risk. Factors reflected in the "everything else" index likely include the effects of economic slow-downs on the amount and type of highway travel as well as demographic trends such as an increase in the number of older drivers and the movement from central cities to outer suburbs where roadway travel is more frequent and speeds are higher.

In summary, from 1983 through 2012, the vehicular risk index fell from 87 to 44, while the index of "everything else" changed from 51 to 43. The effects of significant improvements in behavioral safety during this period are not clearly reflected in this analysis for several reasons. First, it is important to note that the effects of the sharp increase in seat belt use during this period, from less than 60 percent in 1984 to 86 percent in 2012, are incorporated in the vehicular risk index rather than in the "everything else" index. Second, the effects of other traffic safety behavioral improvements such as the reduction in the proportion of alcohol-impaired driving fatalities from more than 40 percent in 1984 to 31 percent in 2012 and other improvements such as safer roadways and improvements to the emergency medical system are obscured by changes in demographic and socioeconomic trends.

The reduction in car and LTV occupants' fatality risk attributable to vehicle safety technologies, totaling 56 percent from 1960 through 2012, can be put in perspective by comparing it to reductions in fatality risk from heart disease, cancer, and other diseases during those years, a time of legendary advances in pharmacology, surgery, and preventive medicine. For that purpose, it is necessary to identify a measure of risk from diseases that is intuitively comparable to the vehicular fatality-risk index and that also can be computed from available health statistics. One important characteristic of fatal crashes is that they result in **premature** death – i.e., certainly earlier than a person would have died if there had been no crash. The comparison statistic for diseases would not be all deaths, but premature deaths. To the extent that 70 years has historically been considered a full life, fatality rates from diseases among people younger than 70 might at first glance appear to be a good comparison statistic.

However, an important feature of the vehicular risk index in Figure A is that the effect of demographic and geographic trends has been filtered out; the meaning of the index is **invariant**, so to speak, from year to year. That would not be true of fatality rates from diseases for all people younger than 70. Because the birth rate generally declined after 1960, the population under 70 has included an increasing share of people over 50 and a decreasing share of young people – and that, by itself, would push fatality rates from diseases upward over time. But the fatality rates from diseases **from 60 to 70** are nearly invariant measures of risk, because the average age in that limited cohort changes little over time.[3] The rate in 1960 would be directly comparable to the rate in 2010. The fatality rates from diseases for people 60 to 70 years old make intuitively good comparison statistics with the vehicular risk index, even though the latter pertains to occupants of all ages, not just 60 to 70.

Figure B compares the vehicular fatality-risk index (unchanged from Figure A; same blue circles) to the fatality rate from all diseases for people 60 to 70 years old, indexed to 100 in 1960 (black line and squares) and specifically to the approximate rates from heart disease (red line and hearts) and cancer (green line and crescents), also indexed to 100 in 1960. The indices for diseases are estimated at 10-year intervals from 1960 to 2010 (as described in Appendix D of this report) and interpolated.

The revolution in vehicle safety compares favorably with the revolution in health over the same 50 years. The index for all diseases fell from 100 in 1960 to 55 in 2010. In other words, the likelihood of dying between 60 and 70 was 45-percent lower in 2010 than it was in 1960, a great reduction in the risk of premature death. But the vehicular fatality-risk index did even better over the whole period, dropping to 46 in 2010 and 44 by 2012. The vehicle safety technologies reduced the probability of dying in a crash by 56 percent from 1960 to 2012. Figure B shows that the risk index for all diseases initially did better than the vehicular risk index, because the first safety technologies were not widely implemented in production vehicles until the mid-to-late 1960s and then needed several years to replace the pre-FMVSS vehicles already on the road. But the vehicular index begins catching up after 1984, pulls even in about 2000, and since then has actually outpaced the reduction in fatal diseases.

Progress against heart disease has been truly extraordinary. The index was 35 in 2010, a 65-percent reduction in the risk of dying of heart disease between 60 and 70. Based on research and a deeper understanding of what causes heart disease, a remarkable combination of medicines, diet, life-style modification, and, when necessary, surgical procedures have helped prevent heart disease, while innovations in emergency care, medicine, and surgery have helped save people after heart attacks. Importantly, most of these innovations, including preventive drugs and diet, take effect relatively quickly and minimize the lag time to realize a benefit. Nevertheless, the vehicular risk index has not done badly in comparison. Since 1985, the vehicular risk index has declined in parallel to the heart disease index and mirrored the rate of decrease, year by year.

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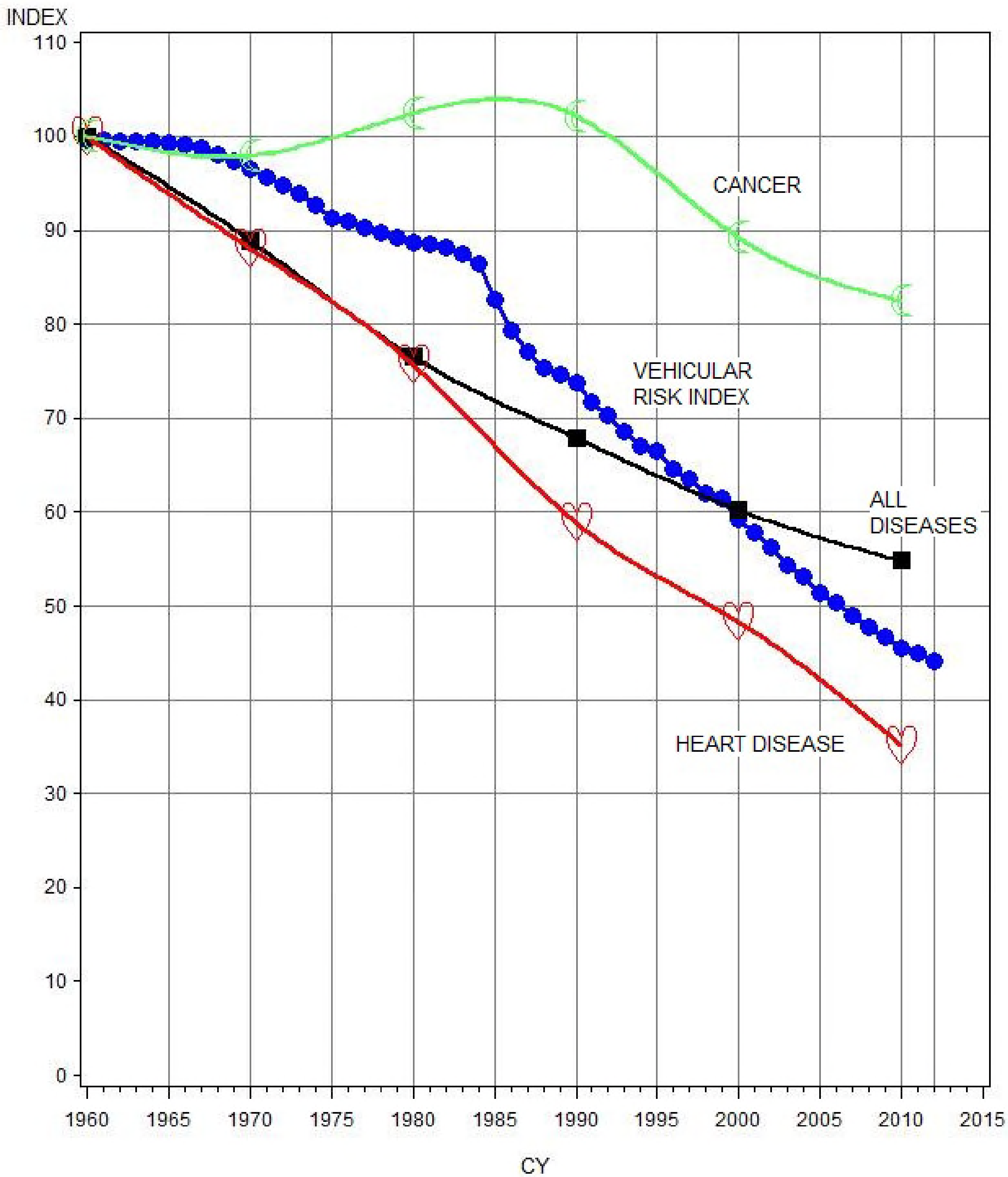
[3] The median age in the United States of all people younger than 70 was 27.2 in 1960, but a substantially older 33.6 in 2010; however the median age of people between 60 and 70 was 64.7 in 1960 and a nearly identical 64.3 in 2010 (sources: www.cdc.gov/nchs/data/statab/pop6097.pdf and www.census.gov/prod/cen2010/briefs/c2010br-03.pdf).

FIGURE B: FATALITY-RISK INDICES BY CALENDAR YEAR (1960 = 100)
VEHICULAR RISK INDEX FOR CAR AND LTV OCCUPANTS
COMPARED TO RISK INDICES OF DYING FROM DISEASES AT AGES 60 TO 70



The index for deaths from cancer between 60 and 70 has not fared nearly as well in comparison to the vehicular risk index. Cancer, of course, is a complex group of diseases and the basic research to understand it still continues. Furthermore, an important weapon in the fight against cancer is life-style modifications such as smoking cessation. But unlike heart disease, it can take many decades of not smoking or not working around hazardous substances before a payoff of lower fatality risk – longer than the lag time to install new safety technologies into most of the vehicles on the road. Figure B shows the cancer index perhaps even became slightly worse before it began to significantly improve: the index (as estimated from the data in Appendix D) went up to 102 in 1980 and 1990, possibly reflecting the long-term effects of increased numbers of new smokers in the 1940s and 1950s – people who were in their 60s by 1980 or 1990.[4] The tide turned after 1990 with a 20-point drop in the index by 2010, catching up somewhat with the index for all diseases, but still not quite keeping up with the rate of improvement in vehicle safety.

[4] Shopland, D. R., Burns, D. M., Samet, J. M., & Gritz, E. R. (eds.) (1991, October). *Strategies to Control Tobacco Use in the United States – A Blueprint for Public Health Action in the 1990s.* (Smoking and Tobacco Control Monograph No. 1, NIH Publication No. 92-3316, Chapter 3). Bethesda, MD: National Cancer Institute. Available at cancercontrol.cancer.gov/Brp/tcrb/monographs/1/m1_complete.pdf

EXECUTIVE SUMMARY

NHTSA began in 1975 to evaluate the effectiveness of vehicle safety technologies associated with the Federal Motor Vehicle Safety Standards. By 2004, NHTSA had evaluated virtually all of the life-saving technologies introduced in passenger cars and in LTVs (light trucks and vans – i.e., pickup trucks, SUVs, minivans and full-size vans) from about 1960 through the mid-1990s. These were retrospective evaluations with estimates of fatality-reducing effectiveness based on statistical analyses of the actual crash experience of production vehicles equipped with the technologies. In October 2004, the agency issued a report estimating the number of lives saved from 1960 to 2002, year-by-year, by the combination of those life-saving technologies and by each individual technology; the estimates added up to 328,551 lives saved through 2002.[5]

Since 2004, NHTSA has evaluated nine additional life-saving technologies, such as ESC and curtain air bags and has acquired 10 additional years of crash data (through 2012). Although some of these technologies, including ESC and curtains were already available in production vehicles by 2002, they could not be included in the previous report because the vehicles had not yet accumulated enough on-the-road experience for statistical analyses. This report updates the 2004 study and estimates 613,501 cumulative lives saved from CY 1960 through 2012. The update includes not only new estimates of 281,042 lives saved from CY 2003 through 2012 (the years not included in the earlier report), but also a slight upward revision from the previous report's estimate of 328,551 to 332,459 for CY 1960 through 2002 to account for the technologies that had begun to appear in production vehicles by 2002 but had not yet been evaluated by 2004.

Past evaluation reports estimated the **effectiveness** of a safety technology – a percentage reduction of fatalities – by statistically analyzing crash data. An initial evaluation is based on production vehicles produced just before versus just after a make-model received that technology. Effectiveness might subsequently change over time if vehicles and/or the crash environment changes; when feasible, NHTSA tracks effectiveness with follow-up evaluations of crash data based on later vehicles. These follow-up analyses show that effectiveness has remained quite stable for key safety technologies such as seat belts, frontal air bags, and ESC. But the **benefits** of a technology – the absolute number of lives saved in a year – readily change from year to year depending on the number of vehicles equipped with the technology, their VMT, and the crash-involvement rate of the driving population (exposure). This report will:

- Review the effectiveness estimates in past evaluations of safety technologies for cars and LTVs, describing how the technologies work and the history of the FMVSS that regulate them.

- Develop a model that uses Fatality Analysis Reporting System data and these past effectiveness estimates to calculate how many lives the following technologies have saved, individually and in combination, in each year from 1960 to 2012:

[5] Kahane, C. J. (2004, October). *Lives saved by the Federal Motor Vehicle Safety Standards and other vehicle safety technologies, 1960-2002*. (Report No. DOT HS 809 833). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/809833.PDF.

FMVSS: Safety Technologies	Cars	LTVs	Heavy Trucks
105/135: Dual master cylinders & front disc brakes[6]	X	X	
108: Conspicuity tape for heavy trailers			X[7]
126: Electronic stability control[8]	X	X	
201: Voluntary mid/lower instrument panel improvements	X	X	
Head-impact upgrade	X	X	
203/204: Energy-absorbing steering assemblies	X	X	
206: Improved door locks	X	X	
208: Lap belts	X	X	
3-point belts	X	X	
2-point automatic belts[9]	X		
Voluntary NCAP-related improvements for belted occs.[10]	X		
Belt pretensioners and load limiters	X	X	
Frontal air bags (barrier-certified, sled-certified, advanced)	X	X	
212: Adhesive windshield bonding	X	X	
213: Child safety seats	X	X	
214: Side door beams	X	X	
Structure and padding to meet a dynamic side-impact test	X		
Curtain and side air bags	X	X	
216: Roof crush resistance (eliminate true hardtops)	X		
226: Ejection mitigation (rollover curtains)	X	X	
301: Fuel system integrity: rear-impact upgrade	X	X	

In addition to safety equipment compliant with a specific FMVSS in effect at that time (and perhaps even excelling the performance requirements of that FMVSS), the model tallies lives saved by installations in advance of the FMVSS and by non-compulsory improvements shown in the preceding list, such as belt pretensioners and load limiters. The model includes car/LTV occupants saved by car/LTV technologies or child safety seats (99 percent of the total) plus pedestrians/bicyclists/motorcyclists saved by car/LTV brake improvements, motorcyclists saved by ESC, and car/LTV occupants saved by conspicuity tape on heavy trailers.

The model does not include technologies so recent that NHTSA has not yet evaluated them based on statistical analysis of crash data, such as tire pressure monitoring systems (phased in during MY 2006 to 2008). The study is limited to technologies in cars and LTVs or that save lives of car/LTV occupants; for example, motorcycle helmets are not included. It is limited to vehicle technologies. It does not estimate the effects of behavioral safety programs such as the reduction of impaired driving – except to the extent that buckle-up programs have contributed greatly to the number of lives saved by belts and child safety seats. It does not include effects of

6 Applied to cars and LTVs, but also saves pedestrians, bicyclists and motorcyclists not hit by these cars and LTVs.
7 Applied to heavy trailers, but also saves occupants of cars and LTVs that avoid collisions with these trailers.
8 Applied to cars and LTVs, but also saves motorcyclists not hit by these cars and LTVs.
9 LTVs were not equipped with 2-point automatic belts.
10 NCAP testing, the dynamic side impact test of FMVSS No. 214, and FMVSS No. 216 apply to LTVs as well as cars, but NHTSA evaluations have not identified a life-saving effectiveness for the LTVs.

roadway and traffic engineering improvements (such as rumble strips), shifts in the vehicle fleet – e.g., between large and small cars or between cars and LTVs, or improvements in EMS or follow-up medical care. The model is limited to estimating fatality reduction by the safety technologies; NHTSA does not have sufficiently complete evaluation results to develop comparable estimates for the numbers of nonfatal injuries prevented.

<u>How the model works</u>: Consider 1,000 cases of driver fatalities in directly frontal multivehicle crashes in cars with 1960 technology: no energy-absorbing steering columns, all drivers unbelted, and no air bags. A NHTSA evaluation estimates that energy-absorbing steering columns reduce fatalities of drivers in frontal crashes by 12.1 percent. Thus, if these cars had been equipped with them, there would have been only 879 fatalities, a saving of 121 lives. Another evaluation estimates that 3-point belts, in cars with energy-absorbing steering columns, reduce drivers' fatality risk by 42 percent in these types of crashes. If the cars had been equipped with 3-point belts in addition to energy-absorbing steering columns and the drivers had buckled up, the 879 fatalities would have diminished to 510, saving another 369 lives. A third evaluation estimates that frontal air bags reduce fatality risk by 25.3 percent for belted drivers in these types of crashes, in cars with energy-absorbing steering columns. Frontal air bags would have cut the 510 fatalities down to 381, saving another 129 lives.

The model uses 1975-to-2012 FARS data and performs the same calculations in reverse order: e.g., there might be 381 actual FARS cases of 3-point-belted driver fatalities in directly frontal multivehicle crashes in MY 1999 cars, all of which were equipped with frontal air bags and energy-absorbing steering columns. If frontal air bags, the most recent (1990s) of these three safety technologies, had been removed from the cars, fatalities would have increased to an estimated 510. In other words, we surmise there must have been 129 potentially fatal collisions of these MY 1999 cars that did not become FARS cases because frontal air bags saved the driver's life. If the 3-point belts, a 1970s technology, had also been removed from the cars and all the drivers had been unbelted, the fatalities would have increased to 879. Finally, if the energy-absorbing steering columns, a 1960s technology, had been replaced by rigid columns, downgrading these cars all the way back to a 1960 level of safety, fatalities would have increased to 1,000. The three technologies, in combination, saved an estimated 619 lives: 129 by air bags, 369 by 3-point belts and 121 by energy-absorbing columns. In summary, FARS cases of fatalities in vehicles equipped with modern safety technologies constitute evidence of an even larger hypothetical number of fatalities that would have occurred without those technologies. This approach "removes" the technologies in reverse chronological order; alternative approaches removing them in some different order would still have estimated 619 overall lives saved from 1960 to 2012, but might have allocated that total differently among the individual safety technologies.

FARS data has been available since 1975, but the FMVSS date back to January 1, 1968, and some technologies were introduced even before that. An extension of the model allows estimates of lives saved from 1960 to 1974.

<u>Lives saved from 1960 to 2012</u>: Safety technologies saved an estimated 613,501 lives from 1960 through 2012. Table 1 shows that the annual number of lives saved grew from 115 in 1960, when a small number of people used lap belts, to 27,621 in 2012, when most cars and LTVs were equipped with numerous modern safety technologies and belt use on the road achieved 86 percent. This is a large increase from the previous NHTSA study, which estimated 328,551 lives

saved from 1960 through 2002. Table 1 shows that vehicle safety technologies had great benefits during the decade from 2003 through 2012, saving between 26,000 and 31,000 lives each year.

Figure 1 tracks the estimated benefits of vehicle safety technologies. Fewer than 1,000 lives per year were saved during 1960 to 1967. Starting in 1968, vehicles incorporating most of the safety improvements of the 1960s superseded older vehicles; lives saved reached 4,000 in 1978, but remained at that level for 6 years as belt use temporarily declined. The greatest increase, from 4,835 in 1984 to 11,265 in 1988, came with buckle-up laws in the States. From 1988 until 2007, continued increases in belt use; air bags, ESC, and other recent technologies; and an expanding "base" of more vehicles and more VMT helped the fatality reduction grow, exceeding 15,000 in 1994 and 20,000 in 1999, reaching a peak of 30,312 in 2007. From 2007 until 2011, however, even though safety technologies continued to save a growing share of the potential fatalities, a shrinking "base" of VMT, especially the high-risk VMT, contributed to a decrease in the absolute number of lives saved, down to 26,098 in 2011, but then rebounding to 27,621 in 2012.

<u>Car/LTV occupants: actual fatalities, potential fatalities and percent saved</u>: Among the 613,501 lives saved in 1960 to 2012, 610,566 were occupants of cars and LTVs. (The remaining 2,935 were pedestrians, bicyclists, and motorcyclists who avoided fatal impacts by cars or LTVs because dual master cylinders, front disc brakes, or ESC improved the car or LTV's braking or handling performance.) The sum of the actual fatalities and the lives saved is the number of fatalities that potentially might have happened if cars and LTVs still had 1960 safety technology and nobody used seat belts. Table 2 shows 1,712,855 actual car/LTV occupant fatalities from 1960 through 2012; without the 610,566 lives saved, there would have been 2,323,421 potential fatalities. Actual car and LTV occupant fatalities decreased from 28,183 in 1960 to 21,696 in 2012. Without the vehicle safety technologies and increases in belt use, the model estimates that fatalities would not have declined but would have substantially increased, from 28,298 in 1960 to 49,214 in 2012.

Figure 2 compares the trends in actual and potential fatalities. Up to the early 1980s, both trend lines were fairly close together. Both moved up or down in response to the large cohort of baby boomers starting to drive in the1960s; the same cohort in the 1970s turning 25, an age when fatal-crash involvement rates are already substantially lower than in adolescence; plus transient reductions in the mid-1970s and early 1980s, perhaps triggered by events such as an energy crisis, high fuel prices, or an economic slowdown. From the mid-1980s, vehicle safety made a big difference. Potential fatalities have historically continued to rise as the number of registered vehicles and VMT increased in an affluent society – with transient interruptions from 1989 to 1992 and 2006 to 2011. But increased belt use, air bags, ESC, and other vehicle safety technologies held the line on actual fatalities at about 32,000 a year during the two decades of generally rising potential fatalities and then helped bring them down to levels not seen since the 1940s, such as 21,331 in 2011 and 21,696 in 2012.[11]

[11] The chapter titled "Car/LTV occupant fatalities per 100,000,000 VMT" in Part 2 of this report presents additional discussion, including references, of factors (other than vehicle safety technologies) that influenced fatality rates between 1960 and 2012.

Table 1: Lives Saved by Vehicle Safety Technologies, 1960 to 2012
(Car and LTV Occupants Saved, Plus Non-Occupants and Motorcyclists
Saved by Car/LTV Brake Improvements or ESC)

CY	LIVES SAVED
1960	115
1961	117
1962	135
1963	160
1964	203
1965	251
1966	339
1967	509
1968	816
1969	1,179
1970	1,447
1971	1,774
1972	2,226
1973	2,576
1974	2,518
1975	3,058
1976	3,240
1977	3,671
1978	4,040
1979	4,299
1980	4,540
1981	4,455
1982	4,057
1983	4,248
1984	4,835
1985	6,389
1986	8,531
1987	9,992
1988	11,292
1989	11,522
1990	11,761
1991	12,250
1992	12,573
1993	13,902
1994	15,263
1995	16,265
1996	17,956
1997	18,751
1998	19,613
1999	20,256
2000	22,280
2001	23,364
2002	25,691
2003	27,174
2004	28,253
2005	29,936
2006	30,242
2007	30,312
2008	27,941
2009	26,770
2010	26,695
2011	26,098
2012	27,621
	===========
	613,501

FIGURE 1: LIVES SAVED PER YEAR BY VEHICLE SAFETY TECHNOLOGIES, 1960 TO 2012

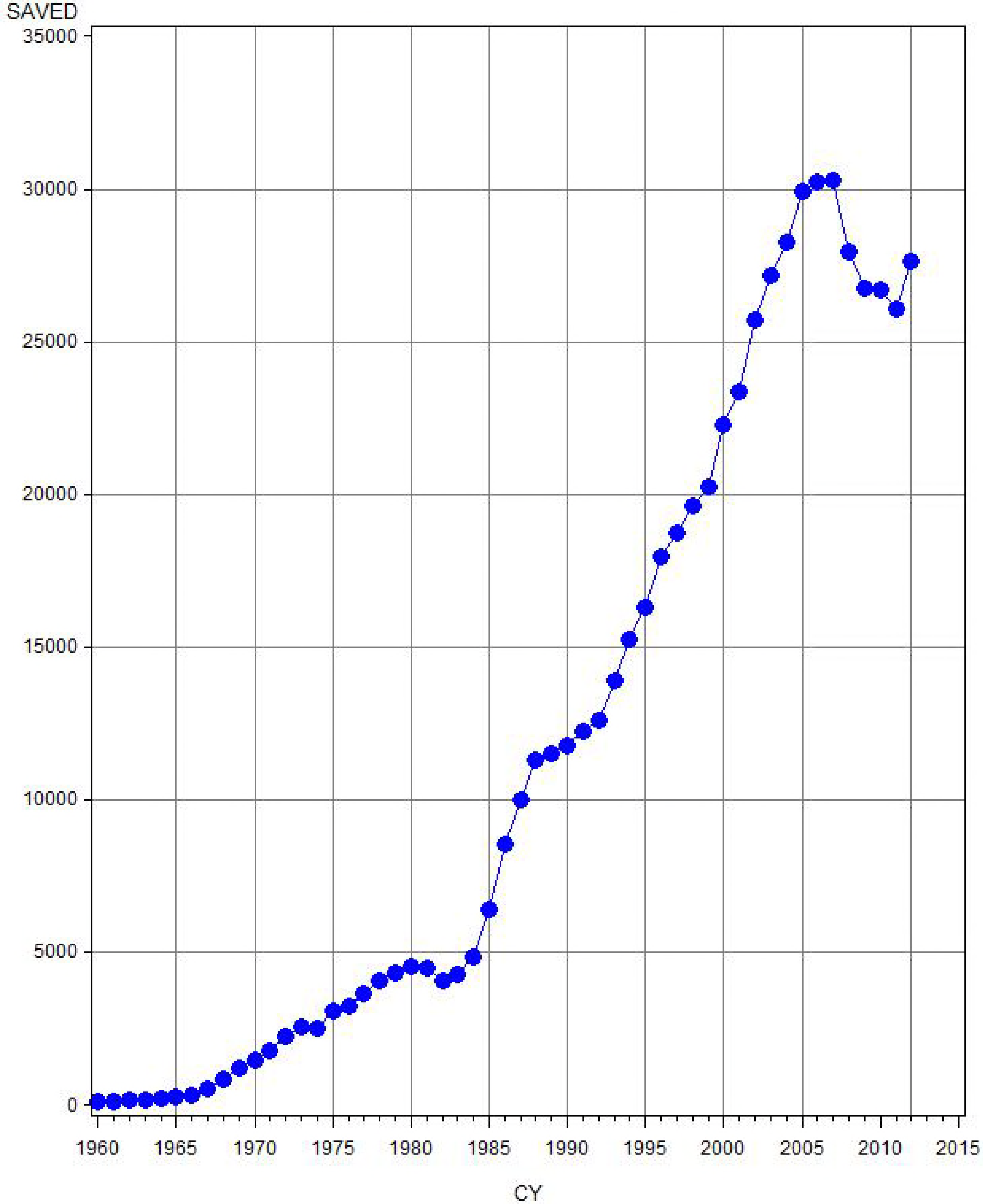
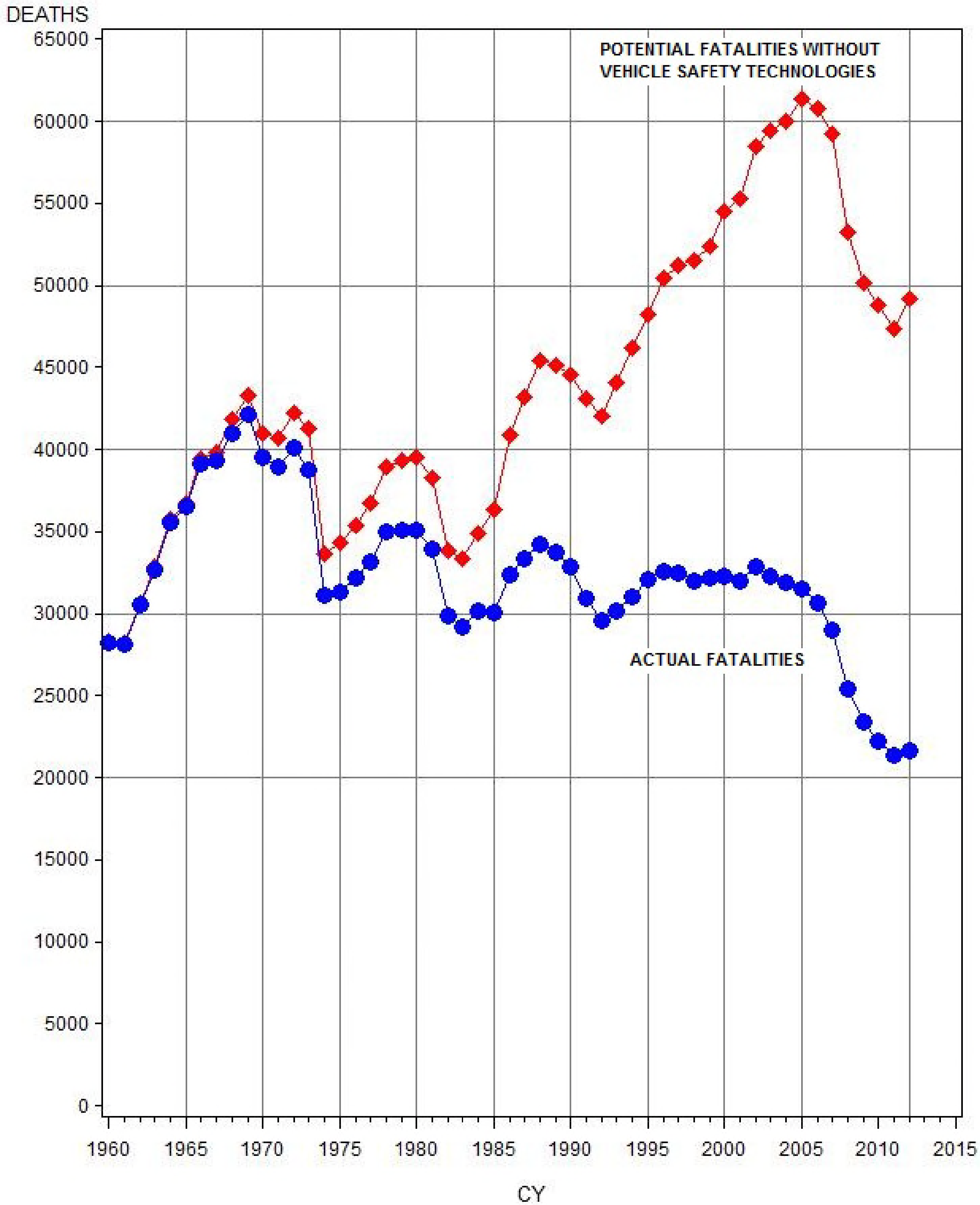


Table 2: Actual Occupant Fatalities, Potential Fatalities Without The Vehicle Safety Technologies, and Lives Saved in Cars/LTVs

CAR+LTV OCCUPANT FATALITIES

CY	ACTUAL	W/O SAFETY TECHS.	LIVES SAVED	PERCENT SAVED
1960	28,183	28,298	115	0.40
1961	28,087	28,204	117	0.41
1962	30,544	30,679	135	0.44
1963	32,664	32,823	159	0.49
1964	35,603	35,805	202	0.56
1965	36,518	36,767	249	0.68
1966	39,130	39,465	334	0.85
1967	39,327	39,826	499	1.25
1968	41,019	41,818	799	1.91
1969	42,117	43,273	1,156	2.67
1970	39,556	40,972	1,415	3.45
1971	38,916	40,651	1,735	4.27
1972	40,103	42,281	2,178	5.15
1973	38,739	41,258	2,520	6.11
1974	31,145	33,608	2,463	7.33
1975	31,361	34,355	2,995	8.72
1976	32,222	35,398	3,176	8.97
1977	33,173	36,772	3,599	9.79
1978	34,988	38,951	3,964	10.18
1979	35,108	39,325	4,217	10.72
1980	35,097	39,554	4,456	11.27
1981	33,911	38,284	4,373	11.42
1982	29,855	33,834	3,979	11.76
1983	29,209	33,384	4,176	12.51
1984	30,177	34,935	4,758	13.62
1985	30,044	36,357	6,314	17.37
1986	32,394	40,849	8,454	20.70
1987	33,334	43,251	9,916	22.93
1988	34,245	45,461	11,216	24.67
1989	33,725	45,177	11,452	25.35
1990	32,844	44,534	11,690	26.25
1991	30,939	43,126	12,187	28.26
1992	29,557	42,071	12,514	29.75
1993	30,192	44,033	13,840	31.43
1994	30,995	46,200	15,204	32.91
1995	32,067	48,271	16,204	33.57
1996	32,541	50,438	17,897	35.48
1997	32,515	51,208	18,693	36.50
1998	31,955	51,512	19,557	37.97
1999	32,171	52,373	20,202	38.57
2000	32,241	54,465	22,225	40.81
2001	32,021	55,327	23,306	42.12
2002	32,872	58,506	25,634	43.81
2003	32,297	59,411	27,114	45.64
2004	31,871	60,064	28,193	46.94
2005	31,539	61,408	29,869	48.64
2006	30,633	60,804	30,171	49.62
2007	29,009	59,246	30,236	51.04
2008	25,423	53,287	27,864	52.29
2009	23,417	50,115	26,698	53.27
2010	22,235	48,852	26,617	54.49
2011	21,331	47,342	26,011	54.94
2012	21,696	49,214	27,518	55.92
	===========	===========	===========	
	1,712,855	**2,323,421**	**610,566**	

FIGURE 2: ACTUAL VERSUS POTENTIAL CAR/LTV OCCUPANT FATALITIES, 1960 TO 2012



The overall, combined **effectiveness** of the vehicle safety technologies is the percentage of potential fatalities that were saved, as shown in the right column of Table 2. The effectiveness grew in **every** year from 1960 to 2012, from a humble 0.40 percent in 1960 to a very substantial 55.92-percent fatality reduction in 2012. Figure 3 charts the trend, showing:

- Not much effect before the FMVSS;
- Steady growth in the early-to-mid 1970s as the early FMVSS phased in;
- A slowdown in 1978 to 1982, when belt use declined prior to national buckle-up campaigns;
- The largest gains coming with the buckle-up laws in the mid-to-late 1980s; and
- Steady progress since the late 1980s thanks to continued increases in belt use, air bags, ESC, and other recent technologies.

Figure 4 tracks a **vehicular fatality-risk index** for occupants of cars or LTVs that isolates the effects of vehicle safety improvements. The index is obtained by subtracting from 100 the percentage of potential fatalities saved. The index was 100 in 1955 and had declined to 44 by 2012. In other words, given the same mileage by the same driver on the same roads, the average vehicle on the road in 2012 would have 56 percent lower fatality risk for its occupants than the average vehicle on the road in 1955.

FIGURE 3: PERCENT OF POTENTIAL FATALITIES SAVED
BY VEHICLE SAFETY TECHNOLOGIES, 1960 TO 2012

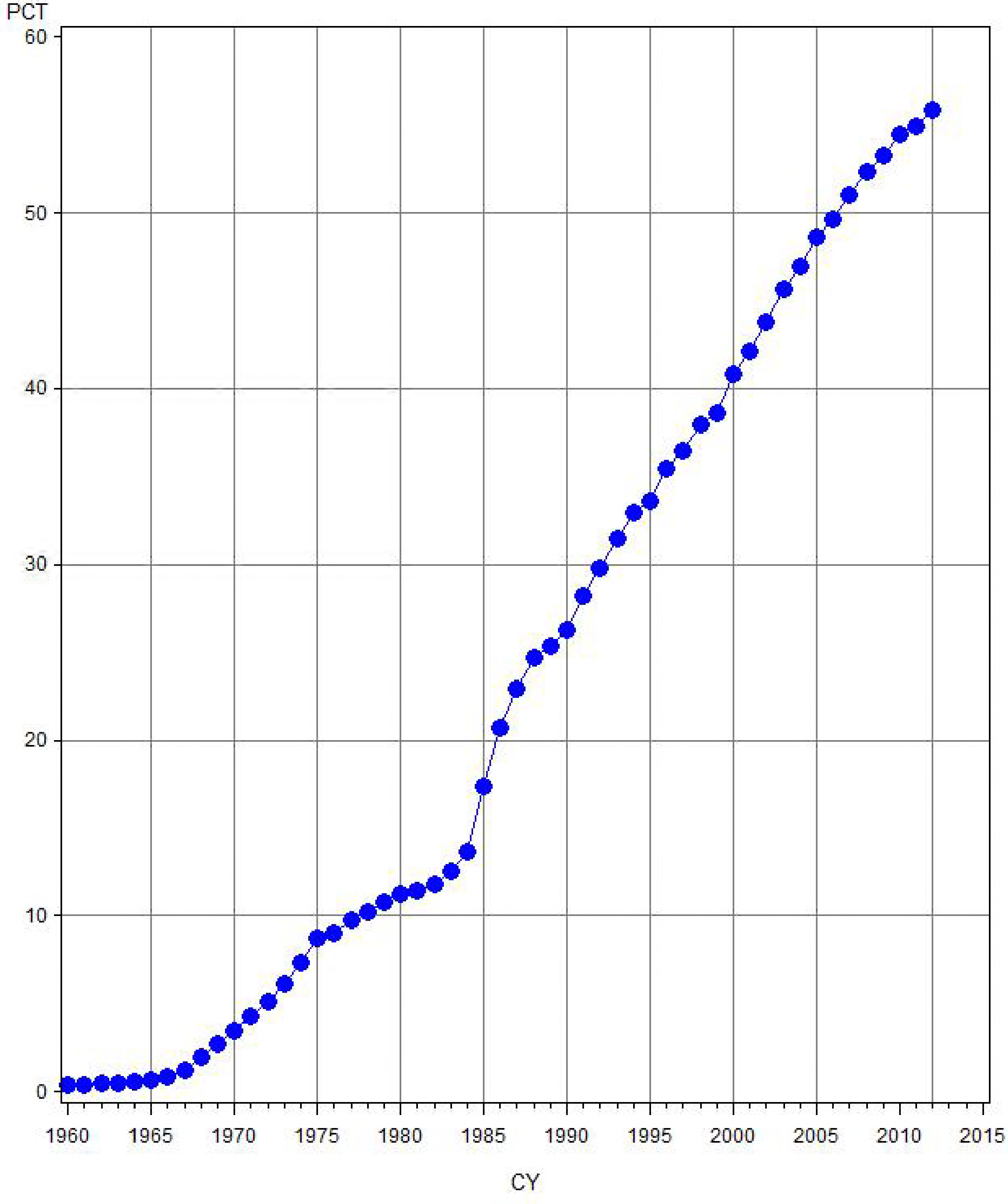
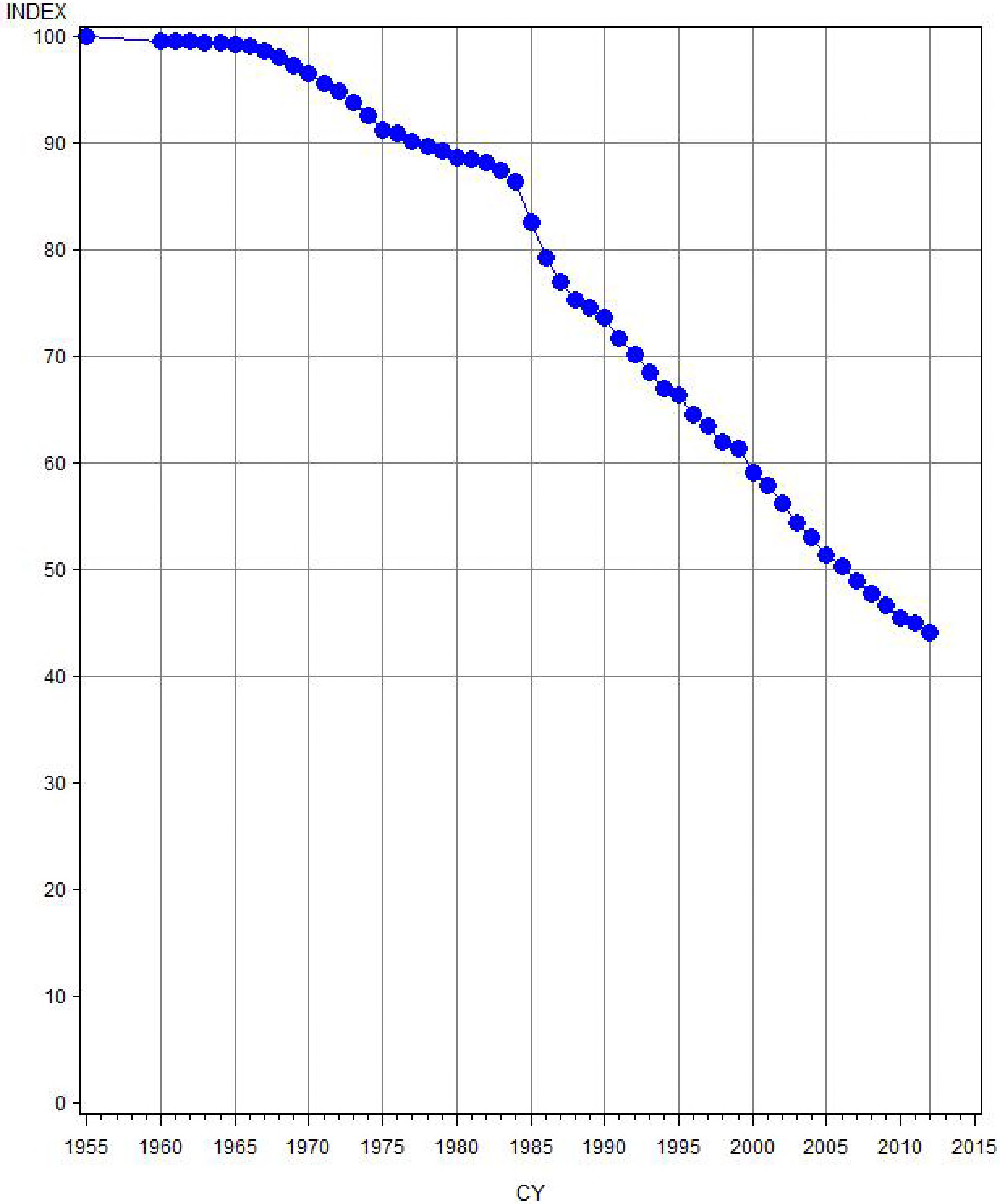


FIGURE 4: VEHICULAR FATALITY-RISK INDEX BY CALENDAR YEAR (1955 = 100)
BASED ON PERCENT OF POTENTIAL FATALITIES SAVED BY VEHICLE SAFETY TECHNOLOGIES



Estimates of lives saved by individual technologies (grouped by FMVSS): Car/LTV safety technologies saved an estimated 27,621 lives in 2012. That total includes 14,018 car occupants and 13,500 LTV occupants. It also includes 103 pedestrians, bicyclists and motorcyclists saved by car/LTV braking improvements or by ESC. Table 3 apportions how many of those lives were saved by the various individual technologies and groups those technologies according to the FMVSS with which they appear to be most closely associated:

- Seat belts are by far the most important occupant protection, saving an estimated 15,485 lives[12]: over half the total of 27,621. The estimate includes seat belts of all types (3-point, lap-only, automatic), at all designated seating positions. Seat belts are designed to keep occupants within the vehicle and close to their original seating position, provide "ride-down" by gradually decelerating the occupant as the vehicle deforms and absorbs energy, and, if possible, prevent occupants from contacting harmful interior surfaces or one another (however, NHTSA recommends correctly installed, age-appropriate safety or booster seats for child passengers until they are at least 8 years old, unless they are at least 4'9" tall). Seat belts are especially important in LTVs, where a large proportion of unrestrained fatalities are ejections and/or rollover crashes; belts saved 8,316 lives in LTVs, over 60 percent of the 13,500 LTV occupants saved.

- Frontal air bags saved 2,930 lives in 2012, when 95 percent of cars and 91 percent of LTVs on the road were equipped with dual or driver-only frontal air bags.[13] Frontal air bags have significant benefits in frontal and partially frontal impacts for nearly all occupants 13 and older, including the oldest drivers and passengers, by providing energy absorption and ride-down and by preventing head contacts with the windshield or windshield header. However, a deployed frontal air bag, especially some of the pre-2007 designs without the advanced features of current models, can present risks to child passengers 12 and younger. The risk can be eliminated if the child rides in the rear seat, correctly restrained – or by turning off the manual on-off switch in pickup trucks or other vehicles where children cannot ride in a rear seat correctly restrained.

[12] NHTSA's **official** estimate is that belts **directly** saved 12,174 lives in 2012 – i.e., fatalities would have increased by 12,174 if nobody had buckled up, but otherwise the cars and LTVs on the road had remained unchanged. [Source: NCSA. (2014, March). *Traffic safety facts 2012 Data – Occupant Protection*. (Report No. DOT HS 811 892). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/811892.pdf.] This report's estimate, 15,485 lives saved in 2012, is higher because it also includes some indirect savings: this report estimates how many additional fatalities would have occurred if **all** safety technologies had been removed, not just the belts, and it then **apportions** the total among the various individual technologies. Accounting for the lives directly saved by recent technologies such as ESC, by this report's computational method, also indirectly augments the estimates of lives saved by earlier technologies such as seat belts (as explained in Part 2 of this report). The estimates here **do not supersede** the agency's official estimates of lives directly saved by seat belts, frontal air bags, and safety seats. They are primarily meaningful within the context of this report: estimation of the overall effect of all the vehicle safety technologies and apportionment of the overall effect among the individual technologies.

[13] NHTSA's official estimate in *Traffic safety facts 2012 Data – Occupant Protection* is 2,213 lives saved directly by air bags in 2012.

Table 3: Estimates[14] of Lives Saved by Safety Technologies in 2012

FMVSS & Associated Safety Technologies	Car Occupants	LTV Occupants	Pedestrians Bicyclists Motorcyclists	TOTAL
105/135: Dual master cylinders & front disc brakes	217	201	65	482
108: Conspicuity tape for heavy trailers	90	70		161
126: Electronic stability control for cars and LTVs	500	824	38	1,362
201: Instrument panel improvements & head impact protection	778	573		1,350
203/204: Energy-absorbing steering assemblies	1,323	1,084		2,407
206: Improved door locks	486	641		1,127
208: Seat belts – all types, all seating positions[15]	7,169	8,316		15,485
208: Frontal air bags	1,738	1,193		2,930
212: Adhesive windshield bonding	177	95		271
213: Child safety seats	213	145		357
214: Side impact protection & curtain/side air bags	1,196	315		1,512
216: Roof crush resistance (eliminate true hardtops)	122			122
226: Curtains that deploy in rollovers	3	41		43
301: Fuel system integrity – rear impact upgrade	5	4		9
TOTAL	14,018	13,500	103	27,621

[14] All estimates in this table are rounded to the nearest whole number. Estimates might not add up exactly to row or column totals because of the rounding.

[15] Estimates in this table for seat belts, frontal air bags, and child safety seats do not supersede NHTSA's official annual estimates in *Traffic safety facts 2012 Data – Occupant Protection* of the lives directly saved by those technologies. The footnotes on the preceding page explain that the estimates in this table, which also include estimates of lives indirectly saved by those technologies, are meaningful primarily in this report's context of computing the overall effect of the FMVSS and the comparing the effects of various FMVSS; they also explain why the estimates on this page differ from *Traffic safety facts*.

- Energy-absorbing steering assemblies meeting FMVSS Nos. 203 and 204 are an important "built-in" safety technology that saved an estimated 2,407 lives in 2012. In the 1960s, they were the first basic protection for drivers in frontal crashes, designed to cushion their impact into the steering assembly. Today, the combination of energy-absorbing steering columns, seat belts and frontal air bags provides far better protection for the driver in frontal crashes.

- Three groups of technologies associated with FMVSS No. 214, "Side impact protection" saved an estimated 1,512 lives in 2012. The technologies are: (1) Side door beams in cars and LTVs meeting the original static crush test of FMVSS No. 214, which are primarily effective in side impacts with fixed objects, such as trees or poles; (2) Structures and padding added to passenger cars before or after FMVSS No. 214 was upgraded in the 1990s with a dynamic test requirement, which are primarily effective in near-side impacts by other vehicles; and (3) Curtain and side air bags, which further enhance protection in near-side impacts.[16]

- Electronic stability control (now required in new cars and LTVs by FMVSS No. 126) saved 1,362 lives in 2012, the first year when all new cars and LTVs had ESC – but in 2012 only 20 percent of cars and 22 percent of LTVs on the road were ESC-equipped. Benefits can be expected to grow substantially in future years as the on-road fleet approaches 100 percent ESC-equipped. ESC detects when a vehicle is about to lose traction and automatically applies the brakes to individual wheels and/or reduces engine torque to help the driver stay on course. It is a highly effective crash avoidance technology.

- Two groups of technologies associated with FMVSS No. 201, "Occupant protection in interior impact" saved an estimated 1,350 lives in 2012. The technologies are: (1) Improvements to the materials and contours of middle and lower instrument panels in the late 1960s and 1970s, not specifically required by FMVSS No. 201 but historically and functionally associated with that standard to some extent; instrument panels were redesigned, using energy-absorbing materials, to decelerate occupants at a safe rate and keep them in an upright position during frontal crashes. (2) The head-impact upgrade of FMVSS No. 201, phased in during MY 1999 to 2003, which added energy-absorbing padding to pillars, roof headers, roof side rails, and other components that were sources of life-threatening head injuries.

- Improvements to door locks, latches, and hinges, generally implemented by manufacturers in the 1960s and regulated by industry standards subsequently incorporated into FMVSS No. 206, saved 1,127 lives in 2012. They reduce the risk of occupant ejection by keeping doors closed in rollover crashes.

- Car/LTV braking improvements directly or indirectly associated with FMVSS Nos. 105 and 135 include dual master cylinders and front disc brakes. By eliminating brake failure or helping cars and LTVs stop more effectively, they saved 482 lives in 2012, including 65 pedestrians, bicyclists or motorcyclists.

[16] A "near-side" impact is a left-side impact for the driver and a right-side impact for the RF passenger.

- Child safety seats or booster seats meeting FMVSS No. 213 saved an estimated 357 young passengers in 2012.[17] Child safety seats and booster seats are the basic protection system for passengers who are too small to obtain full benefits from seat belts. Newborns should start with rear-facing seats and stay in them until their weight or height reaches a point where they should graduate to forward-facing seats, subsequently to booster seats and, finally, when they are at least 9 years old or 4'9" tall, to adult seat belts.

- Adhesive windshield bonding saved 271 lives in 2012 by keeping the windshield attached to the vehicle in severe impacts and preventing occupant ejection via the windshield portal. FMVSS No. 212 regulates windshield retention for cars and LTVs.

- FMVSS No. 108 requires red-and-white conspicuity tape on heavy truck trailers. The tape reflects another vehicle's headlights strongly and it is highly visible in the dark. Although this device is furnished on heavy trailers, not cars or LTVs, it is the occupants of cars and LTVs who primarily benefit by avoiding collisions with the trailers. The tape saved an estimated 161 car and LTV occupants in 2012.

- FMVSS No. 216, "Roof crush resistance" is associated with the redesign of true hardtops as pillared hardtops or sedans during the 1970s. True hardtops had no B-pillars to support the roof, making it more susceptible to crush in a rollover. If cars were still built that way there might have been 122 additional fatalities in 2012.

- FMVSS No. 226, "Ejection mitigation" began to phase in during MY2014. Curtain air bags that deploy in rollover crashes are the key technology for meeting the standard. Rollover curtains have already been available in some production vehicles since 2002. They are effective in preventing ejection and mitigating interior impact. They saved an estimated 43 lives in 2012.

- The rear-impact test of FMVSS No. 301, "Fuel system integrity" was substantially upgraded during the past decade. The upgrade saved an estimated 9 lives in 2012: people who otherwise would have died of burns in post-crash fires.

Table 4 shows cumulative lives saved from 1960 through 2012: 385,408 car occupants and 225,158 LTV occupants, plus 2,936 pedestrians, bicyclists and motorcyclists saved by car/LTV braking improvements or ESC, for an estimated total of 613,501. Seat belts (329,715) accounted for more than half the total. Frontal air bags had saved 42,856 lives by the end of 2012 and child safety seats, 9,891. The "built in" non-belt technologies regulated by or associated with the remaining 13 FMVSS in Table 4 (Nos. 105/135, 108, 126, 201, 203/204, 206, 212, 214, 216, 226, and 301) sum to 231,039 lives saved; energy-absorbing steering assemblies, improved door locks, occupant protection in interior impact, and side impact protection have cumulatively saved the most lives.

[17] NHTSA's official estimate in *Traffic safety facts 2012 Data – Occupant Protection* is 284 lives saved directly by child safety seats in 2012.

Table 4: Estimates[18] of Cumulative Lives Saved by Safety Technologies From 1960 Through 2012

FMVSS & Associated Safety Technologies	Car Occupants	LTV Occupants	Pedestrians Bicyclists Motorcyclists	TOTAL
105/135: Dual master cylinders & front disc brakes	10,559	5,001	2,790	18,350
108: Conspicuity tape for heavy trailers	1,524	1,136		2,660
126: Electronic stability control for cars and LTVs	2,420	3,604	146	6,169
201: Instrument panel improvements & head impact protection	24,779	9,698		34,477
203/204: Energy-absorbing steering assemblies	57,112	22,877		79,989
206: Improved door locks	25,377	16,758		42,135
208: Seat belts – all types, all seating positions	187,442	142,274		329,715
208: Frontal air bags	27,765	15,091		42,856
212: Adhesive windshield bonding	7,268	2,585		9,853
213: Child safety seats	7,257	2,634		9,891
214: Side impact protection & curtain/side air bags	28,971	3,317		32,288
216: Roof crush resistance (eliminate true hardtops)	4,913			4,913
226: Curtains that deploy in rollovers	8	171		178
301: Fuel system integrity – rear impact upgrade	14	13		26
TOTAL	385,408	225,158	2,936	613,501

[18] All estimates in this table are rounded to the nearest whole number. Estimates might not add up exactly to row or column totals because of the rounding.

Comments on some assumptions in the "lives saved" model: The fatality-reducing effectiveness estimates used in the model are all derived from published NHTSA evaluation reports. The model only includes a technology if its estimate of fatality reduction in NHTSA evaluations is statistically significant. As stated above, the estimates are based on statistical analyses of crash data. An initial evaluation report usually compares fatality risk in vehicles built just before and just after make-models became equipped with the technology, statistically controlling for factors other than the technology by using double-pair comparison, control groups, logistic regression, or other techniques. For some technologies, including seat belts, frontal air bags, ESC, and curtain and side air bags, the agency has performed follow-up evaluations of crash data involving later vehicles to see if effectiveness might have changed over time.

The basic assumption of the model is that any group of FARS fatality cases involving vehicles equipped with a safety technology known to be effective in that type of crash may be considered evidence that there were additional crashes where that technology saved lives: these additional crashes are not on FARS because the technology made them nonfatal crashes. For example, if there are 100 belted fatality cases on FARS in a type of crash where statistical analysis shows 50-percent belt effectiveness, we surmise that there must have been another 100 people in potentially fatal crashes who were saved by the belt. This is a leap of faith to the extent that we cannot identify those 100 specific occupants who were "saved by the belt" – we assume they must exist, based on our effectiveness estimate.

The model simulates "removing" safety equipment from a modern vehicle one piece at a time, starting with the most recent technology and working backward. Some of these technologies were introduced at about the same time, and it is not always obvious which was first: for some of the earliest ones, limited information is available about their introduction dates. Changing the order in which the technologies are "removed" would still produce the same estimate of overall lives saved, but the allocation among the individual technologies could change.

The model assumes that the belt use of **fatally injured** occupants (not survivors) on FARS is accurately reported. NHTSA has long believed this to be true, based on statistical analyses comparing FARS data with belt use observed in surveys. In the future, conceivably, event data recorders could provide additional evidence on belt use in crash data files.

Finally, when the model says vehicle safety technologies saved 613,501 lives, it estimates that this number of additional fatalities might have occurred from 1960 through 2012, without those technologies, if all other factors had stayed the same: the same increase in VMT from 1960 to 2012, the same driving behaviors. It is a hypothetical estimate. If seat belts and the other modern vehicle safety technologies had never been invented and if occupant fatalities had continued climbing toward 61,000 instead of remaining near 32,000, as shown in Table 2, the public might have demanded much stronger regulation of drivers (e.g., licensing) or the infrastructure (e.g., speed limits). Consumers might have purchased a different mix of vehicles and some people might have been more reluctant to travel during the riskiest hours (e.g., weekend nights). Those measures might have prevented at least some of the additional 613,501 fatalities – but surely not as efficiently and with as little impairment of driving enjoyment and mobility as the vehicle safety technologies.

LIVES SAVED BY VEHICLE SAFETY TECHNOLOGIES AND ASSOCIATED FEDERAL MOTOR VEHICLE SAFETY STANDARDS, 1960 TO 2012

FRAMEWORK FOR THE ANALYSIS

NHTSA began to evaluate the effectiveness of vehicle safety technologies and associated Federal Motor Vehicle Safety Standards in 1975, well before Executive Order 12291 (February 1981), Executive Order 12866 (October 1993), Executive Order 13563 (January 2011), and the Government Performance and Results Act of 1993 required Federal agencies to evaluate their existing regulations. By June 2014, NHTSA had issued 82 retrospective evaluations of individual safety standards, programs or technologies; Appendix B of this report summarizes the results of those evaluations.[19]

A typical evaluation estimates the **effectiveness** of a safety technology – a percentage reduction of fatalities, injuries and/or crashes – by statistically analyzing crash data on vehicles produced just before versus just after receiving the technology. It may also estimate the **benefits** of that technology – absolute numbers of lives saved, injuries avoided, or crashes avoided per year – by applying effectiveness estimates to baseline numbers of annual fatalities, injuries or crashes. “Baselines” have typically been the year that a report was written.

NHTSA has evaluated the major crash avoidance and crashworthiness standards in effect for passenger cars and LTVs (which comprise pickup trucks, SUVs, CUVs, minivans and full-size vans) as of June 2014. The agency has also evaluated consumer information on vehicle safety such as NCAP and statistically analyzed safety technologies that are not mandatory for cars or LTVs under Federal regulations, such as pretensioners and load limiters for seat belts.

By now, the agency has evaluated virtually all the life-saving technologies introduced in cars and LTVs from about 1960 up to 2010. Having estimated the lives saved by each individual technology, we are now ready to assess the overall effect of vehicle safety improvements by essentially adding up the individual estimates. “Building up an estimate one technology at a time” is the most empirical and defensible way to estimate how many lives are saved by all the vehicle safety technologies. It is preferable to a complex statistical analysis of the long-term reduction in overall fatality rates per 100,000,000 VMT that attempts to tease out the relative effects of vehicle, behavioral, roadway and demographic factors.

Estimating the combined net lives saved by the vehicle safety technologies, as well as the lives saved by each individual technology in each year updates a 2004 NHTSA report that presented an estimate of 328,551 lives saved from CY 1960 through 2002.[20]

[19] “Executive Order 12291 – Federal Regulation," *Federal Register* 46 (February 19, 1981): 13193; “Executive Order 12866 – Regulatory Planning and Review," *Federal Register* 58 (October 4, 1993): 51735; ; “Executive Order 13563 – Improving Regulation and Regulatory Review," *Federal Register* 76 (January 21, 2011): 3821; *Government Performance and Results Act of 1993*, Public Law 103-62, August 3, 1993.
[20] Kahane (2004, October).

Basic analysis method

We will rely on the individual effectiveness estimates (percentage reductions) developed in past NHTSA evaluations. But it is not as simple as merely adding up past reports' estimates of lives saved per year. The absolute estimates in the various reports are not directly comparable and they are no longer accurate today, because they involve many different, past baselines: typically, the baseline is the number of fatalities on FARS in the year the report was written and this number varies from year to year.

Instead, a process is needed that applies the effectiveness estimates in a consistent manner to appropriate "baseline" numbers of fatalities. FARS data serves as the starting point, indicating the actual number of fatalities every year from 1975 to 2012 in the fleet of cars and LTVs that was on the road. The FARS cases comprise a mix of vehicles, some built recently and meeting many of the FMVSS, others quite old and pre-FMVSS. Because the number of fatalities varies somewhat from one calendar year to the next, applying the effectiveness estimates will result in estimates of lives saved that vary somewhat from year to year.

Every 100 actual fatality cases on FARS represent a potentially even greater number of fatalities that could have happened if the vehicles had not been equipped with any of the safety technologies associated with the FMVSS. The process begins with the actual FARS fatality cases and computes how many additional fatalities there would have been if the vehicles had not been equipped with any safety technologies. The computations rely on the effectiveness estimates from past evaluations. For example, given that 3-point belts reduce fatality risk by 45 percent in cars, 100 belted FARS fatality cases are equivalent to 100/(1 - .45) = 182 fatalities without belts – i.e., we surmise there must have been 182 belted occupants involved in crashes that would have been potentially fatal without belts, but 82 of them did not become FARS fatality cases, because the belts saved the occupant's life. The process is repeated for other safety technologies until all of them have been "removed" from the vehicle – until the vehicle has been downgraded to a level of safety performance characteristic of the 1950s rather than its actual model year. The technologies are removed in the reverse chronological order that they were historically introduced into vehicles. At each step back into the past, the model tallies the lives saved by the latest safety technology – i.e., the additional fatalities that would have occurred if that technology had been removed. This is the process that NHTSA already uses to estimate the number of lives saved by frontal air bags, seat belts, and child safety seats, but expanded to also count the benefits of the other technologies associated with the FMVSS.[21] "Reverse chronological order" is not the only approach that could have been used in the model; alternative approaches are considered in Part 2 of this report (Summary of the Estimation Method). However, the various techniques would have generated the same estimate of overall lives saved in 1960 to 2012, differing only in how they allocated that total among the individual safety technologies.

The model produces unbiased estimates of the lives saved by the various technologies and it is not an exercise in double counting, because the effectiveness estimates in past evaluations are based on analyses of vehicles produced **just after** versus **just before** the installation of the technology in question (e.g., two MY just after versus two MY just before the installation). They estimate the **incremental** effect of that technology on a vehicle that is already equipped with all of the earlier technologies. For example, NHTSA's evaluation of frontal air bags was a study of

[21] *Traffic safety facts 2012 Data – Occupant Protection*.

cars, some without air bags and some with frontal air bags, but all equipped with 3-point belts and energy-absorbing steering columns. The evaluation of 3-point belts was based on older cars equipped with energy-absorbing steering columns but not yet with air bags. The evaluation of energy-absorbing steering columns was based on even older cars without air bags or 3-point belts. These effectiveness estimates are incremental, and they may be applied in reverse-chronological sequence to estimate the total fatality reduction for the combination of the three technologies.[22]

What is included and what is excluded?

This will be a study of the lives saved from 1960 to 2012 by vehicle safety technologies that had been implemented in large numbers cars or LTVs from approximately 1960 until 2010, or that were implemented in other vehicles but benefited occupants of cars and LTVs. The short explanation for limiting the study to vehicle safety technologies in general and to these vehicles and this timeframe in particular is that they are the technologies that have been evaluated by NHTSA (see Appendix B) – inclusively enough to add up the lives saved by the individual technologies and say, “Here is the overall impact of the vehicle safety program.”

The benefits of roadway improvements, behavioral safety programs such as the effort to prevent drunk driving, and EMS enhancements are not explicitly included here. One exception: the benefits of two vehicle safety technologies, seat belts and child safety seats, would not have been anywhere near what they are today without all the buckle-up programs that have increased use; the benefits of these behavioral “occupant protection programs” are implicitly and inseparably part of the benefit of seat belts and safety seats. Unlike the vehicle safety technologies, there are generally no easy statistical methods to estimate the effectiveness of specific, individual behavioral or roadway programs. NHTSA does not have a comprehensive set of effectiveness estimates for behavioral or roadway programs, based directly on statistical analysis of crash data, corresponding to what it has for the vehicle programs.

For passenger cars, NHTSA has thoroughly evaluated the life-saving benefits of safety technologies associated with the FMVSS. The set of estimates for LTVs is almost as complete and where there are some gaps, estimates can in most cases be plausibly inferred from the results for cars. The list of evaluations for motorcycles, heavy trucks, and buses is not as complete (although this is a future priority for NHTSA).

The timeframe of vehicle technologies is as up-to-date as feasible. However, some of the rules or technologies introduced after 2005 or so cannot be included because NHTSA is only now acquiring, or has not yet acquired enough crash data to evaluate their effectiveness in production vehicles.

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[22] Kahane, C. J. (1996, August). *Fatality reduction by air bags: Analyses of accident data through early 1996*. (Report No. DOT HS 808 470, pp. 7-9). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/808470.PDF; Kahane, C. J. (2000, December). *Fatality reduction by safety belts for front-seat occupants of cars and light trucks*. (Report No. DOT HS 809 199, pp. 5-10). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/809199.PDF; Kahane, C. J. (1981, January). *An evaluation of Federal Motor Vehicle Safety Standards for passenger car steering assemblies*. (Report No. DOT HS 805 705, pp. 197-203). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/805705.PDF.

For the beginning of the timeframe, it seems most logical to start with the technologies regulated by the initial FMVSS of January 1, 1968. Many of these technologies, however, were actually introduced some years before 1968. For a full picture of the benefits of the FMVSS-era technologies, it makes sense to take the analysis back to 1960, as long as we keep separate accounts of lives saved in pre-FMVSS and FMVSS-compliant vehicles. The oldest technologies regulated by the initial FMVSS include lap belts, introduced in the late 1950s and early 1960s; improvements to door locks throughout the 1960s; and many effective devices introduced in 1965 to 1967. There does not seem to be much point in going back before 1960 or attempting to predict how many fatalities there would be today if cars still had, say, 1905 technology; in any case, NHTSA has not evaluated safety improvements that long preceded the FMVSS era, such as enclosed, metal car bodies, hydraulic brakes, safety glass, or electric headlamps.

One feature of the estimation model in Part 2 of this report is that estimates for the later technologies (such as air bags or 3-point belts) are unaffected by the inclusion or exclusion of any technology that preceded them. Thus, readers have the option of just subtracting the benefits for the earliest technologies on the list (e.g., lap belts or the 1960s improvements to door locks) if, in their opinion, they ought not to have been included in this report.

In 2004, NHTSA issued a report that, based on the agency's cost analyses of individual FMVSS, estimated the total cost and weight added to cars and to LTVs by all the FMVSS, by model year, from 1968 to 2001.[23] NHTSA plans to update the report to the most recent MY possible; it will be a companion to this report. A supplement to these two reports will compare overall lives saved and costs on a substantial "core" group of FMVSS for which NHTSA has evaluated effectiveness as well as costs.[24]

List of FMVSS, safety technologies, and effectiveness evaluations

Part 1 of this report is a review of 26 FMVSS, plus the NCAP program that provides consumers with information about vehicle safety performance. Part 1 is grouped into 21 chapters. These FMVSS either regulate cars and/or LTVs or they regulate other vehicles/equipment but result in benefits to occupants of cars and LTVs. Part 1 reviews 53 individual safety technologies directly or indirectly associated with FMVSS/NCAP, including 44 that NHTSA has evaluated based on statistical comparisons of the crash experience of vehicles built before and after the introduction of those technologies.

Each FMVSS has a number. The 100-series are crash avoidance standards; the 200-series, crashworthiness; and the 300-series, post-crash fire prevention. Within each series, the numbering is usually chronological.

Each chapter of Part 1 presents the rationale for a FMVSS (or a related group of FMVSS), the safety problem it addresses, and its regulatory history, including major *Federal Register* cita-

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[23] Tarbet, M. J. (2004, December). *Cost and weight added by the Federal Motor Vehicle Safety Standards for model years 1968-2001 in passenger cars and light trucks*. (Report No. DOT HS 809 834). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/809834.PDF.

[24] The supplementary report in 2004 was: Kahane, C. J. (2004, December). *Cost per life saved by the Federal Motor Vehicle Safety Standards*. (Report No. DOT HS 809 835). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/809835.PDF.

tions. For each individual safety technology, Part 1 summarizes what was added or changed in vehicles and how this equipment works, when it was introduced and by whom, and why it might be expected to reduce fatalities, injuries or crashes. The data and statistical methods of NHTSA's evaluations are summarized, with examples if possible and so are the principal findings on effectiveness, benefits, and side effects (if any). NHTSA has statistically analyzed the fatality reduction of almost all technologies discussed in Part 1, although, as discussed below, not all of these analyses showed a statistically significant fatality reduction. Analyses of crash reduction are limited to the 100-series, crash avoidance standards. Nonfatal injury reduction is analyzed when sufficient data is available; however, NHTSA's primary source of detailed data on serious injuries, NASS-CDS is a sample of crashes, not a census like FARS, the agency's database of fatal crashes. For some of the technologies, NASS-CDS does not have enough injury cases to evaluate serious-injury reduction. For technologies that require some action by drivers or other occupants (e.g., seat belts, manual on-off switches for air bags, ABS, head restraints), Part 1 also describes how to use them most effectively.

Table 1-1 lists the 44 safety technologies reviewed in Part 1 that NHTSA has evaluated, grouped by chapter (FMVSS). It summarizes the effectiveness of each technology in reducing fatalities, injuries or crashes (100-series only) of cars and LTVs.

- Yes = NHTSA's evaluation found a statistically significant reduction
- No = the evaluation did not find a significant reduction, despite ample data
- Limited data = the evaluation did not find a significant reduction, but data still limited
- Mixed results = significant reduction on some crash types, significant increase on others
- (Yes), (No) = inferred by analogy (e.g., LTVs from cars, injuries from fatals/crashes)
- Unknown = NHTSA has not performed an evaluation
- N/A = the safety technology was not installed on this type of vehicle

NHTSA's evaluations demonstrated significant benefits of some type – if not a fatality reduction then at least a reduction of injuries, crashes or fires – for 37 of the 44 technologies. The evaluations of rear window defoggers, rear-wheel ABS, DRL, seat back locks, and glass-plastic windshields did not show a significant net benefit despite substantial data (and of these, only seat back locks are required by a FMVSS; rear-wheel ABS and glass-plastic windshields have been phased out of vehicles for some time). The evaluations of LED stop lamps and rear impact guards for heavy trailers also did not show a significant net benefit, but this may have been due to the limited data.

Table 1-1: Safety Technologies Evaluated by NHTSA

		Effectiveness					
		Cars			LTVs		
FMVSS	SAFETY TECHNOLOGY	Fatals	Injuries	Crashes	Fatals	Injuries	Crashes
103: Windshield defrosting and defogging							
	Rear-window defoggers	Unknown	Unknown	No	Unknown	Unknown	Unknown
105: Hydraulic brake systems 135: Light vehicle brake systems							
	Dual master cylinders	Yes	Yes	Yes	Yes	Yes	Yes
	Front disc brakes	Yes	Yes	Yes	Yes	Yes	Yes
	Rear-wheel ABS for LTVs		N/A		No	No	No
	4-wheel antilock brake systems (ABS)	No	Yes	Yes	No	Yes	Yes
108: Lamps, reflective devices							
	Side marker lamps	No	Yes	Yes	No	Yes	Yes
	Center high mounted stop lamps	No	Yes	Yes	No	Yes	Yes
	Retroreflective tape on heavy trailers[25]	Yes	Yes	Yes	Yes	Yes	Yes
	Daytime running lights	No	No	No	No	No	No
	Amber turn signals[26]	Unk	Yes	Yes	Unk	(Yes)	(Yes)
	LED stop lamps		Limited data			Limited data	
121: Air brake systems							
	ABS for heavy trucks and trailers[27]	Lim dat	(Yes)	Yes	Lim dat	(Yes)	Yes
126: Electronic stability control							
	ESC[28]	Yes	(Yes)	Yes	Yes	(Yes)	Yes

[25] Tape installed on heavy trailers is effective in preventing cars and LTVs from hitting those trailers.
[26] Result for LTVs inferred from the evaluation of cars.
[27] ABS on heavy vehicles helps them avoid hitting cars and LTVs; injury reduction inferred from the crash reduction.
[28] Injury reduction inferred from the crash reduction.

Table 1-1 (continued): Safety Technologies Evaluated by NHTSA

		Effectiveness			
		Cars		LTVs	
FMVSS	SAFETY TECHNOLOGY	Fatals	Injuries	Fatals	Injuries
201: Occupant protection in interior impact					
	Voluntary middle and lower instrument panel improvements	Yes	Yes	Yes	Yes
	1999-2003 head injury protection upgrade	Yes	Yes	Yes	Yes
202: Head restraints					
	Head restraints for outboard front seat occupants	No	Yes	(No)[29]	Yes
203: Impact protection from the steering control 204: Steering control rearward displacement					
	Energy-absorbing steering assemblies	Yes	Yes	Yes	Unknown
205: Glazing materials					
	High-penetration resistant (HPR) windshields	No	Yes	(No)	(Yes)
	Glass-plastic windshields	No	No	N/A	N/A
206: Door locks					
	Improved locks, latches and hinges for side doors[30]	Yes	(Yes)	(Yes)	(Yes)
207: Seating systems					
	Seat back locks for 2-door cars	No	No	N/A	N/A

[29] Result for LTVs inferred from the evaluation of cars.
[30] Injury reduction and LTV fatality reduction inferred from the fatality reduction in cars.

Table 1-1 (continued): Safety Technologies Evaluated by NHTSA

		Effectiveness			
		Cars		LTVs	
FMVSS	SAFETY TECHNOLOGY	Fatals	Injuries	Fatals	Injuries
208: Occupant crash protection 209: Seat belt assemblies 210: Seat belt assembly anchorages					
	Lap belts for front seat occupants	Yes	Yes	Yes	(Yes)[31]
	Lap belts for rear seat occupants	Yes	Yes	Yes	(Yes)
	Manual 3-point belts for outboard front seat occupants	Yes	Yes	Yes	(Yes)
	3-point belts for rear seat occupants	Yes	Yes	Yes	(Yes)
	Automatic seat belts	Yes	Unknown	N/A	N/A
	Pretensioners and load limiters for seat belts	Yes	Unknown	Yes[32]	Unknown
	Barrier-certified frontal air bags[33]	Yes	Yes	Yes	Yes
	Manual on-off switches for passenger air bags	Mixed results[34]			
	Sled-certified frontal air bags[35]	Yes	(Yes)	Yes	(Yes)
	Advanced frontal air bags[36]	Yes	(Yes)	Yes	(Yes)
212: Windshield mounting					
	Adhesive windshield bonding[37]	Yes	Yes	(Yes)	(Yes)

[31] "(Yes)" indicates result for LTV injuries inferred from the results for passenger car injuries and LTV fatalities (lap belts and 3-point belts, front and rear seats).
[32] Fatality reduction in CUVs and minivans.
[33] Except that fatalities increased for certain groups of child passengers in cars and LTVs.
[34] Prevents harm if the switch is turned off for child passengers; thwarts the benefit of the air bag if the switch is turned off for adult passengers.
[35] Significantly reduce fatality and injury risk relative to no frontal air bags; also significantly reduce risk for child passengers relative to barrier-certified air bags while preserving the effectiveness of barrier-certified air bags for adult and adolescent occupants.
[36] Significantly reduce fatality and injury risk relative to no frontal air bags; significantly reduce risk for child passengers relative to barrier-certified air bags while preserving the effectiveness of barrier- and sled-certified air bags for adult and adolescent occupants; by allowing phase-out of manual on-off switches, reduced risk of switches being turned off for adult passengers.
[37] "(Yes)" indicates results for LTVs inferred from corresponding results for cars.

Table 1-1 (continued): Safety Technologies Evaluated by NHTSA

FMVSS	SAFETY TECHNOLOGY	Effectiveness: Cars Fatals	Effectiveness: Cars Injuries	Effectiveness: LTVs Fatals	Effectiveness: LTVs Injuries
213: Child restraint systems 225: Child restraint anchorage systems					
	Child safety seats	Yes	Yes	Yes	(Yes)[38]
	Riding in the rear seat	Yes	Unknown	Unknown	Unknown
214: Side impact protection					
	Side door beams	Yes	Yes	Yes	Unknown
	TTI(d) improvement by structure and padding	Yes	Unknown	N/A	N/A
	Curtain and side air bags	Yes	Unknown	Yes	Unknown
216: Roof crush resistance					
	Redesign of true hardtops as pillared hardtops or sedans	Yes	Unknown	N/A	N/A
223/224: Rear impact guards for heavy trailers[39]				Limited data	
226: Ejection mitigation					
	Rollover curtains	(Yes)[40]	Unknown	Yes	Unknown
301: Fuel system integrity					
	1975-1977 upgrade: rollover, rear- and lateral-impact tests	No	Yes[41]	No	No
	2007-2009 rear-impact upgrade	Yes	Unknown	Yes	Unknown
NCAP: New Car Assessment Program					
	Frontal NCAP-related improvements, vehicles w/o air bags	Yes	Unknown	Unknown	Unknown
	IIHS offset-frontal impact	Yes	Unknown	Unknown	Unknown

[38] "(Yes)" indicates result for LTV injuries inferred from the results for passenger car injuries and LTV fatalities.
[39] Rear impact guards on heavy trailers are potentially effective in mitigating fatality and injury risk for occupants of cars and LTVs hitting those trailers.
[40] Result for cars inferred from the evaluation of LTVs.
[41] Significant reduction of crashes with post-crash fires.

The evaluations showed a statistically significant fatality reduction for 31 technologies. The effectiveness estimates for those 31 technologies are the basis for the model that estimates lives saved by vehicle safety technologies in Part 2 of this report. The evaluations of ABS for cars and LTVs, amber rear turn signals, ABS for heavy vehicles, head restraints, HPR windshields, and the 1975-to1977 upgrade of FMVSS No. 301 showed significant reductions of crashes or nonfatal injuries, but they did not show a significant fatality reduction. The effectiveness estimates in Part 1 may be found in published NHTSA reports. Those NHTSA publications are cited in footnotes and listed in the References at the end of this report. Moreover, Appendix B provides capsule summaries of 82 evaluations published as of June 2014, in reverse chronological order.

The effectiveness of a safety technology can vary over time if there are changes in the design of that technology, in the crash environment, or in other features of vehicles (such as installation of other safety technologies). Effectiveness should be reevaluated periodically if feasible. The initial evaluation is often straightforward, statistically comparing vehicles just before versus just after a technology was introduced. Follow-up evaluations of later model-year vehicles may require more complicated statistical tools, because these vehicles may not be directly comparable to the vehicles produced just before the technology was introduced. For many technologies, NHTSA has published only one evaluation; this report assumes the effectiveness in specific crash types has stayed about the same in subsequent years. However, for quite a few technologies, NHTSA has completed one or more follow-up evaluations.

- Technologies with especially large potential benefits: 3-point belts for outboard front seat occupants, frontal air bags, ESC;
- Safety devices whose design has changed over the years: frontal air bags, curtain and side air bags, child safety seats;
- Technologies whose effectiveness might vary as the crash environment or other features vehicles change: 3-point belts, side impact protection by structure and padding; and
- Crash avoidance technologies whose effectiveness may change over time as a result of drivers' knowledge or familiarity with them: ABS, CHMSL, ESC.

The follow-up evaluations showed that the fatality-reducing effectiveness of 3-point belts for outboard front seat occupants, frontal air bags, ESC, and the other technologies listed above have not changed significantly over time. Belt effectiveness has remained stable despite the numerous changes in vehicle design and the crash environment.

Part 1 also summarizes the vehicle modifications and rationale for nine safety technologies that are already available in production cars and/or LTVs, but NHTSA has not yet fully studied the reduction of fatalities, injuries, or crashes, based on statistical analysis of crash data.

- FMVSS No. 138 – tire pressure monitoring systems (TPMS)
- 2010-to-2012 head restraint upgrade of FMVSS No. 202
- Tethers or attachments for child safety seats and their anchorages in the vehicle
- Booster seats (analysis, so far, is limited to nonfatal injuries)
- 2013-to-2016 roof crush resistance upgrade of FMVSS No. 216
- Frontal NCAP-related modifications in vehicles with air bags
- Modifications related to Side NCAP or IIHS side impact testing
- Rollover resistance NCAP-related modifications

Furthermore, the statistical evaluations of side impact protection by structure and padding and of curtain/side air bags have so far been limited to front seat occupants, because data on rear seat occupants is still quite limited – i.e., the estimates of lives saved by vehicle safety technologies will not count any rear seat occupants saved by these two technologies. Later on, when there is sufficient FARS data distinguishing between booster seats and other child safety seats, NHTSA will obtain separate estimates of fatality reduction for booster seats, but for the time being, the agency will assume a single effectiveness number for child safety seats and booster seats.

In addition to the 26 FMVSS reviewed in Part 1, there are 24 other FMVSS (in effect as of June 2014) that regulate new cars, new LTVs, or car/LTV components that have not been evaluated by NHTSA. The evaluation of FMVSS No. 139, "New pneumatic radial tires for light vehicles" will be combined with the future evaluation of the effect of TPMS on crash rates. The following FMVSS definitely or quite possibly resulted in tangible changes to vehicles, but were not evaluated because existing or potentially available data does not adequately identify what vehicles were modified; or because the type of crashes/injuries mitigated by the FMVSS cannot be singled out in available data (or cannot be identified at all); or because there is currently little hope of obtaining enough data for a statistically meaningful analysis of the effect, if any, that could reasonably be expected for that FMVSS.

- 114: Theft protection
- 116: Motor vehicle brake fluids
- 118: Power-operated windows
- 124: Accelerator control systems
- 125: Warning devices
- 129: New non-pneumatic tires for passenger cars
- 219: Windshield zone intrusion
- 302: Flammability of interior materials
- 303: Fuel system integrity of compressed natural gas vehicles
- 304: Compressed natural gas fuel container integrity
- 305: Electric-powered vehicles: electrolyte spillage and electrical shock protection
- 401: Interior trunk release

The following standards have not been evaluated even though they may regulate vehicle subsystems that are important for safety (e.g., tires, mirrors). The agency believes they probably did not result in extensive changes to those subsystems or does not know if they have resulted in changes. In many cases, the FMVSS may have largely incorporated other organizations' standards or industry-wide practices that vehicles had already been meeting for quite some time before 1968.

- 101: Controls and displays
- 102: Transmission shift lever sequence
- 104: Windshield wiping and washing systems
- 106: Brake hoses
- 109: New pneumatic tires
- 110: Tire selection and rims
- 111: Rearview mirrors
- 113: Hood latch systems

- 117: Retreaded pneumatic tires
- 119: New pneumatic tires for vehicles other than passenger cars
- 120: Tire selection and rims for vehicles other than passenger cars

Part 1 ends with Tables 1-2, 1-3 and 1-4 summarizing the effectiveness of safety technologies: their estimated percentage reductions in fatalities, nonfatal injuries and crashes (always specifying to what group of crashes/injuries these percentages apply). Tables 1-3 and 1-4 also specify estimated numbers of nonfatal injuries and crash prevented per year, if such estimates appeared in a NHTSA evaluation report. However, those individual estimates of benefits do not add up to the overall annual crash avoidance and nonfatal-injury reduction by all the technologies, because the agency has not estimated them for all technologies. NHTSA does not have enough "building blocks" to develop models for overall crash avoidance and injury reduction comparable to the analysis of fatal crashes in Part 2 of this report. Furthermore, these individual estimates, in general, are not directly comparable, because the various evaluation reports compute them using different baseline years.

What has changed from NHTSA's 2004 report?

As stated above, NHTSA issued a report in 2004 that estimated vehicle safety technologies had saved 328,551 lives from CY 1960 through 2002.[42] This report updates the estimates through 2012 by incorporating FARS data from 2003 through 2012 into the analysis and by including the effects of safety technologies that NHTSA has evaluated since the previous report.

The effectiveness estimates for the 31 technologies with statistically significant fatality reductions drive the current model to estimate lives saved. Only 22 of those technologies were considered in the model of the 2004 report. Seven of the remaining nine were already available in some production vehicles of MY 2002 or earlier – ESC, curtain and side air bags, the head-impact upgrade of FMVSS No. 201, belt pretensioners and load limiters, manual switches for passenger air bags, redesigned frontal air bags, and rollover curtains – but NHTSA did not yet have estimates of fatality reduction based on crash data. The other two technologies – advanced frontal air bags and the 50 mph rear-impact test for FMVSS No. 301 – were still in the future. Furthermore, the earlier report's effectiveness estimate for side-impact structures and padding is superseded by a 2007 analysis. (The earlier report's estimates for car/LTV ABS are also superseded, by a 2009 analysis, but only for nonfatal crashes and injuries; it will not affect the computation of lives saved.)

The estimates of lives saved in the current report are identical to the 2004 report from CY 1960 (115 lives saved) through CY 1985 (6,389 lives saved). Small differences begin in 1986 (8,531 lives saved here, 8,523 in the earlier report). The current report has new estimates of the effects of side-impact structures and padding. These improvements began gradually on a voluntary basis in MY 1986, even though the upgrade to FMVSS No. 214 did not phase in until MY 1994 to 1997. Because technologies whose effects are included here but not in the earlier report – ESC, curtain and side air bags, etc. – proliferated after 1995, the current report's estimates of lives saved become progressively somewhat higher than the earlier report's (e.g., 25,691 versus 24,561 in 2002).

[42] Kahane (2004, October).

Estimating lives saved by safety technologies, 1960 to 2012

Part 2 of this report focuses on the safety technologies that have significantly reduced fatality risk. The individual effectiveness estimates and the basic analysis method, described above, are applied to FARS data to estimate how many lives were saved from 1960 to 2012. The tables in Part 2 also estimate how many lives were saved.

- In each calendar year
- By each individual safety technology
- Technologies grouped by associated FMVSS
- By vehicle type:
  - Car occupants
  - LTV occupants
  - Pedestrians and motorcyclists saved by car/LTV braking improvements or ESC
- Distinguishing between lives saved by technologies compliant with FMVSS that were in effect at the time and "voluntary" saves such as:
  - Improvements introduced before the effective date of a FMVSS
  - Technologies not required for meeting any FMVSS, although perhaps indirectly associated with a FMVSS because they address the same general safety problem

Part 2 compares the actual number of fatalities from 1960 to 2012, or in any specific year to the number that potentially would have occurred, given the same driving exposure, if none of the cars and LTVs had been equipped with any of the safety technologies. It computes the percentage of the potential fatalities that were saved by the technologies. Part 2 also compares the trends in fatalities per 100,000,000 VMT – with and without the vehicle safety technologies.

Every life-saving technology in Table 1-1 is included in Part 2. Child passengers' "riding in the rear seat," although listed in Table 1-1, is not included in Part 2 because it is not a technology, but the objective of a behavioral safety initiative. Just as Part 2 does not count lives saved by the recent shift of child passengers from front to rear seats among the "benefits of the vehicle safety technologies," it does not count the effects of other market shifts between existing vehicle types, such as between:

- 2-door cars and 4-door cars;
- Large cars and small cars;
- Passenger cars and LTVs; or
- Truck-based SUVs and CUVs.

While these shifts can and do affect the number of fatalities, they cannot be considered benefits of new safety technologies of the FMVSS era. Part 2 considers only their implicit effects on the year-to-year changes in actual and potential fatalities.

PART 1

Review of 26 Federal Motor Vehicle Safety Standards And the New Car Assessment Program

Comprising 53 Safety Technologies

And Their Effectiveness in Reducing Fatalities, Injuries and Crashes for Passenger Cars and LTVs

Following the review of the FMVSS and NCAP, Tables 1-2, 1-3 and 1-4 summarize the fatality-, injury- and crash-reducing effectiveness (percentage reductions) of the safety technologies. Tables 1-3 and 1-4 also summarize annual benefits of individual technologies: injuries and crashes avoided per year. Part 2 of this report estimates the annual fatality reduction, for each technology individually and for all of them together.

FMVSS No. 103, "Windshield defrosting and defogging systems"

A vehicle modification whose safety benefits have been evaluated by NHTSA is grouped with this standard merely because the functions are similar:

- **Rear window defrosting and defogging systems**

FMVSS No. 103 regulates windshield defrosting and defogging. One of NHTSA's initial safety standards, effective on January 1, 1968, it required passenger cars and SUVs to have windshield defroster/defoggers and it set performance requirements for them, incorporating SAE Recommended Practices dating back to 1964. Cars and LTVs had windshield defroster/ defoggers well before 1968. They remained unchanged during the mid-to-late 1960s.[43]

FMVSS No. 103 has never required or proposed to require rear-window defoggers. Their development has been voluntary on the part of the industry, in response to customer demand. Drivers obviously want a clear rear window, and they like a device that clears it for them automatically, so they do not have to wipe or scrape it repeatedly.

History of rear window defoggers: *Ward's Automotive Yearbooks*[44] began to include rear window defoggers in MY 1973 among their statistics for factory-installed equipment in domestic cars by make-model. In that year, 16 percent of new cars were equipped with them; presumably, they were offered in smaller numbers some years before that. Installations grew steadily in the 1970s and 1980s. By 1992, over 90 percent of new cars were equipped with them. By MY 2001, they were standard equipment on most cars, SUVs and minivans, but not pickup trucks or full-size vans; 94 percent of new cars were equipped with them.[45]

How they work: Current rear-window defoggers are grids of electric wires attached to the rear window. The wires are thin enough not to obstruct vision. Controlled by a switch on the instrument panel, they heat up to evaporate condensation or melt ice and snow. The switch automatically turns off after a certain number of minutes, in order to save wear and tear on the system, and the driver has to turn it back on if the window is not clear. During the 1970s some defoggers consisted of an electric heater and blower-motor. That type was gone by 1982.

Rear-window defoggers are potentially useful when: (1) environmental factors such as rain, snow or cold fog or ice up the window; (2) the driver turns on the switch. In warm, dry, sunny conditions, windows are normally clear and defoggers are not needed. The situations that might put condensation, snow or ice on the window include any kind of precipitation; early morning hours when water vapor in the outside air condenses as dew; and very cold weather that can make water vapor inside the vehicle condense on windows. Whereas rear-window defoggers rap-

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[43] *Federal Register* 32 (February 3, 1967): 2414; Up-to-date text of NHTSA regulations may be downloaded from the electronic Code of Federal Regulations, Title 49, www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/Title49/49tab_02.tpl. Regulations other than FMVSS are referenced as Part numbers (e.g., Part 563, "Event data recorders"). FMVSS are referenced as Part 571 followed by the FMVSS number (e.g., Part 571.103 = FMVSS No. 103, "Windshield defrosting and defogging systems").

[44] Southfield, MI: Penton Media, Inc.

[45] Morgan, C. (2004, March). *Evaluation of rear window defrosting and defogging systems*. (Report No. DOT HS 809 724, pp. 1-4). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/809724.PDF.